सत्यमेव जयते

Ministry of Road Transport & Highways
Government of India

Capacity Development Project on Highways in Mountainous Regions

GUIDELINE FOR PLANNING

Published by :
Indian Roads Congress

On behalf of the Government of India,
Ministry of Road Transport & Highways
New Delhi

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Foreword

The road network plays a vital road in the overall development of a country by providing the access to employment, social, health and education. India has a vast area in hilly regions consisting of the Himalayan region from North to North-East, the Central Highlands of Aravali, Vindhya & Satpura ranges, the Sahyadri (Western ghats) and the Eastern ghats. Providing all weather connectivity road network in these hilly regions with extreme climatic conditions, difficult and hazardous terrain, topography and high altitude areas is a tough task. The Ministry of Road Transport & Highways has always taken steps towards the betterment of road transport throughout the country and tackling the problem of roads in hilly regions of the country is one such step.

This Guideline for Planning was prepared through the "Capacity Development Project on Highways in Mountainous Regions," bilaterally implemented by MoRTH and JICA. The project started in 2016 and five guidelines were prepared for sustainable development of hill roads in India. Among the five guidelines, the Guideline for Planning focuses on the following technical topics:

- State-of-the-art reference information for the survey and planning of hill road development with reference to existing Indian manuals and Japanese best practices of existing hill road projects.
- Present the survey work in fixing alignment of hill roads on the basis of IRC:SP:48-1998 "Hill Road Manual" and Japanese practical experiences of existing hill road projects.
- Present the planning of hill roads on the basis of IRC:SP:48-1998 "Hill Road Manual" and Japanese practical experiences of existing hill road projects.
- Points of interest and cautions in view of the planning of hill roads including drainage and structures
- Present four advanced technologies that are beneficial to adapt at the planning stage.
- Good practice in Japan in terms of hill road planning.

The Japanese team as well as the Indian team, especially the Experts from JICA, Counterpart Officials from MoRTH, NHAI & NHIDCL, the Project Director and the Project Team, are to be complimented for their commendable effort in producing these guidelines. Their contribution would go a long way towards the sustainable development of roads in the hilly regions of the country. I hope these guidelines would benefit the engineering fraternity in enhancing their knowledge base & skill

The 27th day of January 2022

(I. K. Pandey)
Director General (Road Development) & Special Secretary
Ministry of Road Transport & Highways
Government of India

PREFACE

India is a vast country with diverse geological, climatic regions. Roads are one of the important elements of transport infrastructure for land surface movement of passengers, goods, ammunition & army –intercity, intracity, rural areas and neighboring counties. Indian road network passes through different terrains including hills and mountains. Mountainous regions consist of Himalayan region from North to North-East, the Central Highlands of Aravalli, Vindhya and Satpura ranges, Western and Eastern Ghats.

These mountainous regions, generally, have extreme climatic condition, difficult and hazardous terrain, topography and vast high-altitude areas. Roads in mountainous areas are often composed of multiple civil engineering structures including bridges and tunnels, and proper maintenance is essential to maintain the road function as a network. The Hill regions including the road networks are affected more frequently by floods due to torrential rainfall, landslides, snow avalanche etc. which compel many sections of road network closed during rainy season and winter season. However, accountability for providing safe, reliable and user comfortable road network ultimately rests with the Government departments.

For hill roads IRC has published numerous guidelines, manuals, codes, etc viz IRC: 52, IRC:48, IRC: SP:91; IRC: SP:108: IRC: SP:113, IRC: 5; etc for guidance and adoption by highway professional & road departments.

Ministry of Road Transport & Highways (MORTH), took up the initiative to frame Guidelines for Planning, Slope protection, Mountain bridge, Mountain tunnel & Operation and maintenance of highways in mountainous regions through technical cooperation from Japan International Cooperation Agency (JICA) in 2016. JICA took site visits of hilly roads in India, collected site problem statement, interacted with Indian experts from MORTH, NHAI, NHIDCL, PWD, IRC, etc and also conducted seminars, webinars, meetings, etc before finalization of following 5 documents;

- Guidelines for Planning
- Guidelines for Slope protection and embankment with advanced technology
- Guidelines for Mountain bridge with advanced Technology

- Guidelines for Tunnel on Arterial Roads in Hill Areas
- Guidelines for Operation and maintenance

The Guidelines for Highways in Mountainous Regions, as prepared by JICA mainly highlights appropriate planning, design principles for promoting safety conscious planning and design of roads, embankment, slope & its operation & maintenance aspect and will go a long way in guiding the highway engineers and planners to make our, hill roads, tunnels, bridges, safer, comfortable and of international standards.

It is quite natural, this JICA publications cannot be expected to cover all the subjects and details of highway engineering and as such should not be considered as a substitute for the Standards and Specifications as well as Codes of Practice.

The intent of this publications is to provide guidance to the engineers with the critical aspects of development of Highways in Mountainous Regions. These guidelines are dynamic in nature and the users, based on their experience, give appropriate feedback so as to enable the Guidelines to be revised/improved from time to time.

(S K Nirmal)
Director General (Road Development) and Special Secretary
Ministry of Road Transport and Highways &
Secretary General, IRC

Dated July, 2022

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CHAPTER 1 INTRODUCTION

1.1 Background

India has a vast area in the mountainous regions consisting of the Himalayan region from North to North-East, the Central Highlands of Aravalli, Vindhya and Satpura ranges, the Sahyadri (Western Ghats) and the Eastern Ghats. Out of the twenty-eight states and the eight union territories, nine states are predominantly in the mountainous regions in North and North East, whereas nine other states have substantial hill areas. The Himalayan region itself covers about a fifth of the country's total area and about 3,000 km of the country's sensitive international borders lie along this region. Economic development and strategic needs have resulted in launching of massive road construction projects in the mountainous regions and the activities in these regions have increased manifold in the recent past.

These mountainous regions, generally, have extreme climatic conditions, difficult and hazardous terrain, topography and vast high-altitude areas. Additionally, the mountainous regions are sparsely populated and basic infrastructural facilities available in more developed plains of hinterland are mostly absent. The mountainous regions and, therefore, the roads are affected by floods consequent to torrential rainfall, land-slide, snow-fall, avalanche etc., compelling certain roads to be kept closed in part of the year, especially during winter months. However, the mountainous regions are rich in natural resources, flora and fauna, and are important to launch development projects, industries, tourism etc.

In view of these diverse problems in hill road development, Ministry of Road Transport and Highways (MoRTH) and Japan International Cooperation Agency (JICA) launched the technical cooperation project "Capacity Development Project on Highways in Mountainous Regions". This technical cooperation project developed a series of five guidelines: (1) planning, (2) slope protection, (3) tunnel, (4) bridge and (5) operation and maintenance based on close consultations between Indian technical officials and JICA Experts.

1.2 Scope of Planning Guideline

The Guideline for Planning, which is referred to "the Guideline" hereafter, covers the survey and planning of hill road development.

The Guideline provides state-of-the-art reference information for the survey and planning of hill road development with reference to existing Indian manuals, such as IRC:SP:48-1998 "Hill Road Manual" and IRC:SP:73-2018 "Manual of Specifications and Standards for Two Laning of Highways with Paved Shoulder", and Japanese best practices of existing hill road projects. In the case where no description is found in the Guideline, readers are recommended to refer to relevant specifications, codes, guidelines and manuals published by MoRTH and IRC. Additionally, considering the vast variations in terrain, climatic and topographic conditions in the mountainous regions of India, a uniform system cannot be obviously applied to all areas. Thus, the readers

are also recommended to refer to existing specifications, codes, guidelines and manuals relevant to specific areas, if any.

1.3 Classification of Hill Roads in India

1.3.1 Classification of Hill Roads

Hill road is a road passing through mountainous or steep terrain. As in the case of other roads, hill roads may be classified as one of the following road types based on IRC:SP:48-1998 "Hill Road Manual" and IRC:52-2019 "Guidelines for the Alignment Survey and Geometric Design of Hill Roads".

(1) National Highways
(2) State Highways
(3) Major District Roads
(4) Other District Roads
(5) Village Roads

And, each classification may also be qualified by a suffix indicative of the maximum laden weight of vehicles in tones which could be related to the road safely.

1.3.2 Classification of Terrain

The classification of the terrain is normally done by means of cross slope of the country viz., slope approximately perpendicular to the centre line of the highway location. The following classification is generally used based on IRC:SP:48-1998 "Hill Road Manual".

	Terrain Classification	Percent cross slope of country
(1)	Plain	0 to 10
(2)	Rolling	Greater than 10 up to 25
(3)	Mountainous	Greater than 25 up to 60 (Hill Road)
(4)	Steep	Greater than 60 (Hill Road)

1.4 Work Sequence of Hill Road Projects

The work sequence of hill road projects is shown in Figure 1-1. The work sequence of hill road projects consists of five stages as follows.

(1) Pre-feasibility study
(2) Feasibility study
(3) Detailed engineering
(4) Construction
(5) Operation and maintenance

Figure 1-1 is prepared based on IRC:SP:19-2001 "Manual for Survey, Investigations and Preparation of Road Projects", and thus includes three preparation stages, i.e. (1) pre-feasibility study, (2) feasibility study and (3) detailed engineering. These three preparation stages are essential because hill road projects should be prepared after thorough investigations, which collect all relevant information and evaluate all possible alternatives to be compatible with technical requirements and consistent with economy. Other two stages, i.e. (4) construction and (5) operation and maintenance, are also essential because hill roads and relevant structures should be properly

constructed, operated and maintained to satisfy the requirements during the service life. Additionally, feedback obtained during the stage of operation and maintenance is expected to be utilized for the preparation stages of future hill road projects.

It should be noted that guidelines for five fields were developed in this technical cooperation project as follows.

(1) Planning

(2) Slope Protection

(3) Tunnel

(4) Bridge

(5) Operation and Maintenance

The scope of the Guideline for Planning is coloured in red in Figure 1-1, and included in feasibility study and detailed engineering. The scopes of the Guidelines for Slope Protection and Advanced Embankment, Tunnel and Bridge are coloured in green, and included in detailed engineering. That of the Guideline for Operation and Maintenance is coloured in blue in Figure 1-1. The readers are recommended to refer to these five guidelines depending on their objectives.

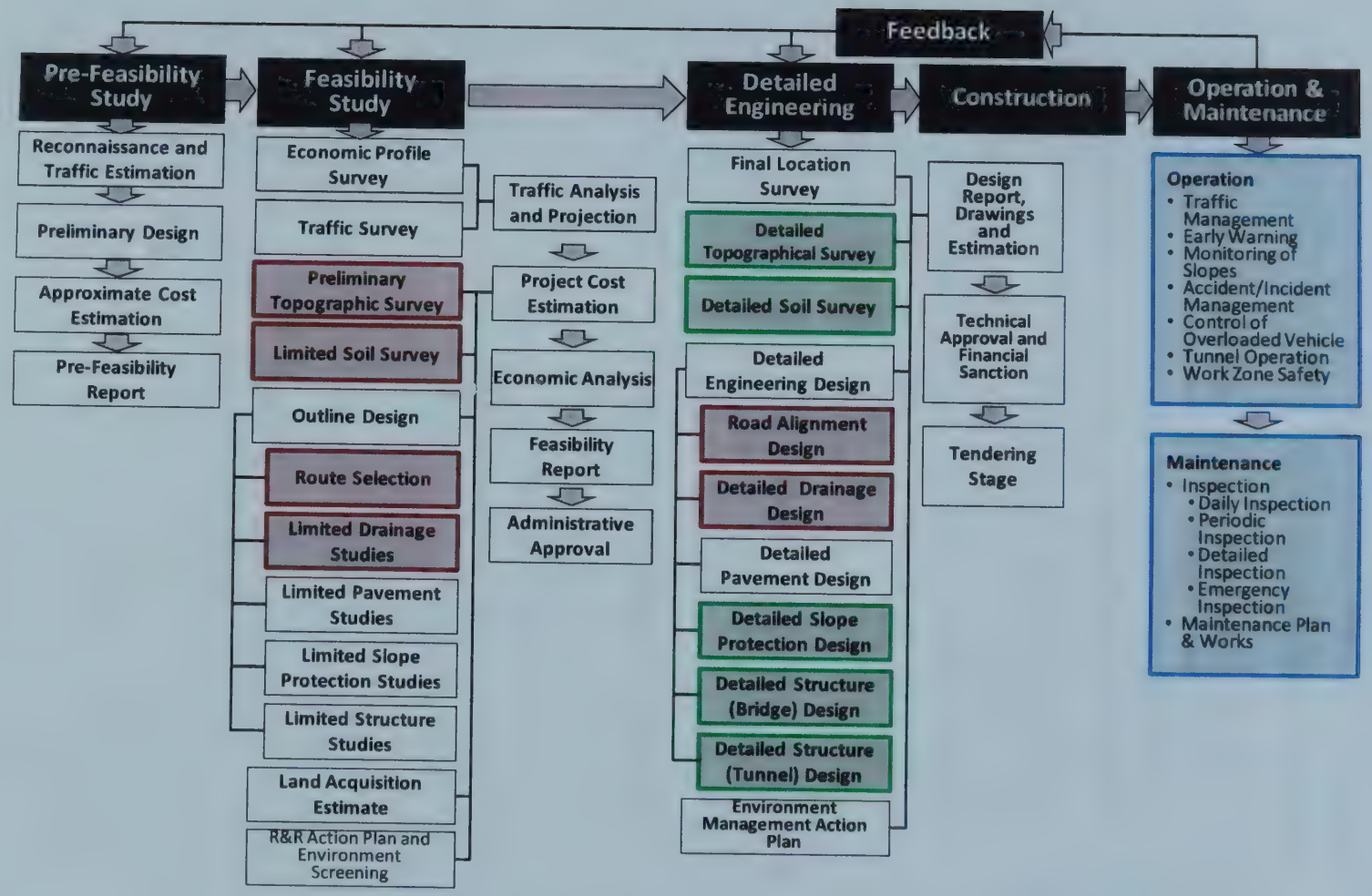


Figure 1-1 Work Sequence of Hill Road Projects

1.4.1 Factors Influencing Hill Road Planning

In the planning stage of hill roads, it is essential to clarify issues related to hill road projects on the basis of the following points.

To recognize the current traffic conditions of road networks

To predict the future traffic demands

To construct new roads or improve existing roads as a part of road networks

It should be noted that the planning of hill roads shall be implemented not only to satisfy the current and future traffic demands but also to deal with other concerns, such as traffic accident and environmental destruction. Additionally, the traffic demand, traffic capacity, and design speed shall be clarified according to the scope of hill road projects. The factors influencing hill road planning are shown as Figure 1-2.

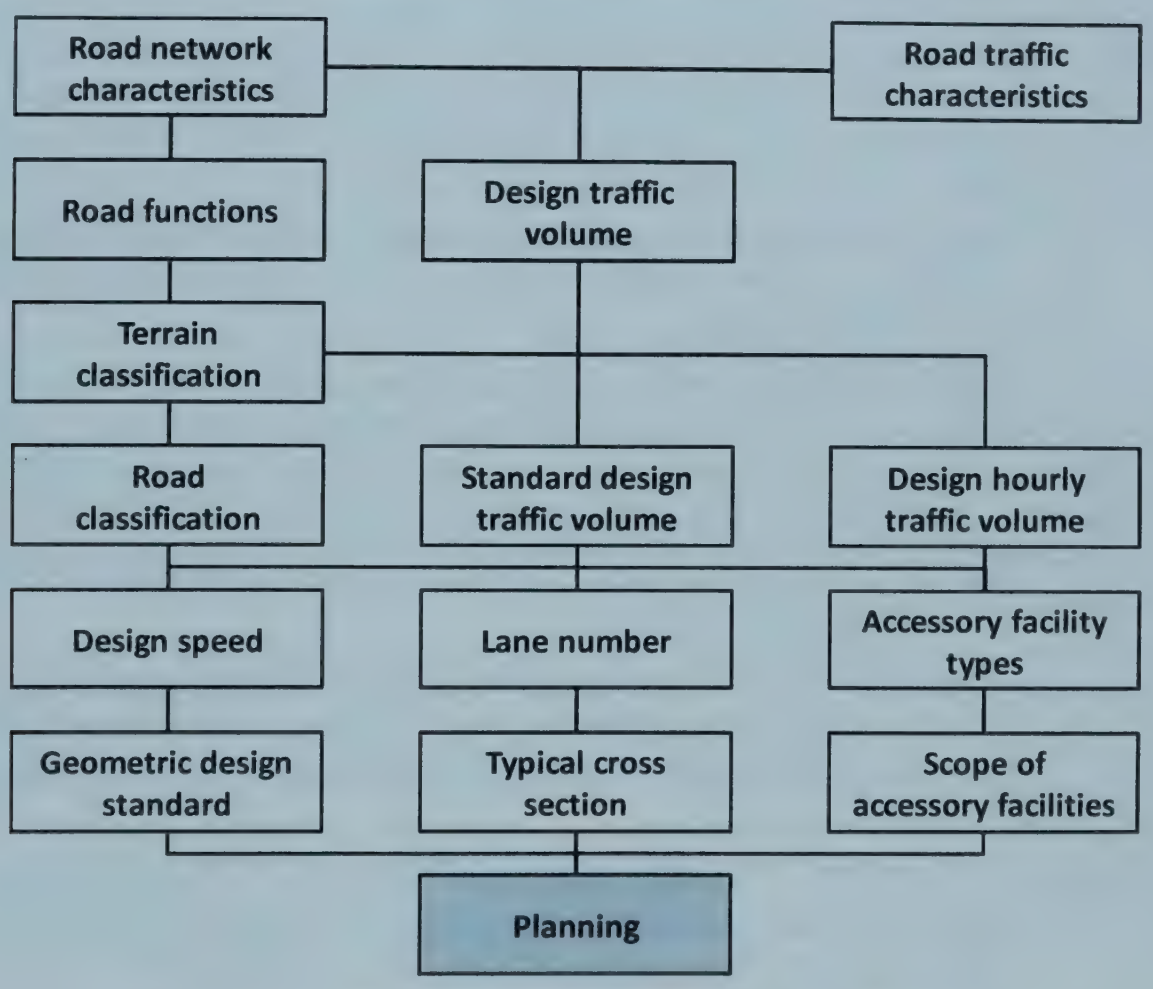


Figure 1-2 Factors Influencing Hill Road Planning

1) **Road network characteristics**: is considered for the future construction of hill roads and their networks. It is essential to clarify the functions of each hill road and the characteristics in the future road networks.

2) **Road traffic characteristics**: is represented by the amount and quality of the traffic to use hill roads. For instance, the total traffic volume, the traffic volume by day of the week (weekdays/holidays), the traffic volume by hour and the composition of the vehicle type, etc.

3) **Road functions**: is divided into three functions: transportation function, land use leading function, and spatial forming function. The transportation function is divided into traffic functions (services for road users and vehicle traffic) and access functions (services to enter and leave roadside buildings and facilities). Both functions are in a trade-off relationship, because the traffic functions are emphasized on high standard highways, and on the other hand, the access functions are more important roads within residences. The land use leading

function is an indirect effect brought by the access function, and performs a major role in the formation of new urban areas. The spatial forming functions perform a particularly important role in urban areas where public spaces are limited for evacuation routes, disaster prevention space, such as a fire interruption prevention blocking section, environment space, such as daylighting, ventilation, playground and social gathering, electricity, telephone, water supply, sewer, subway, parking lot, information box, underground shopping malls and public utility facilities.

4) **Design traffic volume**: is the traffic volume of vehicles, which is the basis of the road planning and is usually represented by the traffic volume per day. The most fundamental factor in determining the scope and configuration of roads is the design daily traffic volume, which is determined by considering the future population of the region, trends in **economic** activity and the number of vehicles owned, etc. [vehicles/day]

5) **Terrain classification**: is normally done by means of cross slope of the country viz., slope approximately perpendicular to the centre line of the highway location. Terrain is classified into four types: plain, rolling, mountainous and steep terrains as mentioned in 1.3.2.

6) **Road classification**: is normally done into five types: national highways, state highways, major district roads, other district roads and village roads as mentioned in 1.3.1.

7) **Standard design traffic volume**: is the traffic capacity per day per one lane (or two lanes), which is used as a basis of the road planning. [vehicles/day]

8) **Design hourly traffic volume**: is the traffic capacity per hour, which is used as a basis of the road planning. The traffic capacity of the route for the target year is calculated based on the annal average daily traffic (AADT). [PCU/hour] (PCU: Passenger Car Unit)

9) **Design speed**: is adopted to hill roads in the range of 20 km/hr to 60 km/hr. It should be noted that the maximum design speed is specified in IRC:SP:73-2018 "Manual of Specifications and Standards for **Two** Laning of Highways with Paved Shoulder".

10) **Lane number**: is classified into **single** lane, Intermediate lane and two lanes.

11) **Accessory facility types**: are **constructed** by roadside amenities, safety facilities, traffic management facilities and so on.

12) **Geometric design standard**: **conforms** to IRC:SP:48-1998 "Hill Road Manual" (Section 6) and IRC:SP:73-2018 "Manual of Specifications and Standards for Two Laning of Highways with Paved Shoulder" (Section 2).

13) **Typical cross section**: **conforms** to IRC:SP:48-1998 "Hill Road Manual" (Section 6: 6.2.7).

14) **Scope of accessory facilities**: is determined based on IRC:SP:48-1998 "Hill Road Manual", considering the conditions of the road planning.

1.4.2 Characteristics of Hill Road Projects

According to IRC:SP:48-1998 "Hill Road Manual", the characteristics of hill road projects are described as follows.

(1) The planning of hill roads is much different from that of roads in plain regions. Villages are small and scattered in valleys and over slopes of numerous hill ranges located at different altitudes. These cannot be connected by straight

road as in the plain regions. Thus, alignment of hill roads has to be circuitous and is primarily governed by topography.

(2) In the mountainous regions, road links should be provided on the basis of cluster or group of villages as far as feasible because the population of each village may be very low. Villages located within a radius of 1.6 km and having an altitude difference of not more than 200 m can be considered as one cluster or group. Isolated villages, having population of more than 500, should be provided with an all-weather link road. For a cluster of villages of population less than 500, a selective approach of an all-weather road within 5 km from the village may be considered to start with. Where funds do not permit construction of regular motor road, road may be constructed for light vehicular traffic to link villages.

(3) Due to topographical constraints and location of small isolated villages, it may not be possible to connect all villages with motorable roads. However, for the development of the area and its economic growth, there is a need to connect all villages and production centres with some means of connection. The isolated villages or habitations can be connected by bridle roads after bringing them within 2 to 3 km of a motorable road, with an altitude difference of, say, not more than 200 m. Gravity type aerial cableways can also be provided for cheaper and easier transportation to road-head from such isolated habitation, where necessary.

(4) As in the rest of the country, hill roads are also classified as national highways, state highways, major district roads, other district roads and village roads according to specifications, traffic needs, socio-economic, administrative or strategic considerations. However, from topographical considerations, these can broadly be divided into arterial roads and link roads. Arterial roads are trunk routes and can be further divided into major valley roads and inter-valley roads. While the former run in major valleys along rivers or streams, or in some cases, depending upon topography, near to the ridge line, the latter traverse through different valleys, connecting one major valley to another either running near to the ridge line or across slope of hill ranges, rising from one valley to the ridge and going down to the next valley and so on, connecting a number of villages to market or administrative centres. Arterial roads will include national highways, state highways and major district roads. Link roads take off from arterial roads to link villages or production areas in small or sub-valleys. These will comprise other district roads and village roads.

1.5 Abbreviations

The abbreviations related to the Guideline are shown as follows.

1) **BRO**: Border Roads Organization
2) **DEM**: Digital Elevation Model
3) **DSM**: Digital Surface Model
4) **EPC**: Engineering, Procurement and Construction Contract
5) **GNSS**: Global Navigation Satellite System
6) **GoI**: Government of India
7) **GPS**: Global Positioning System
8) **IAHE**: Indian Academy for Highway Engineering
9) **IRC**: Indian Road Congress
10) **JICA**: Japan International Cooperation Agency

11) **MLIT**: Ministry of Land, Infrastructure, Transport and Tourism, Japan
12) **MoRTH**: Ministry of Road Transport and Highways
13) **NHAI**: National Highways Authority of India
14) **NHDP**: National Highways Development Project
15) **NHIDCL**: National Highways and Infrastructure Development Corporation Ltd.
16) **OSV**: On Site Visualization System
17) **PCU**: Passenger Car Unit
18) **PO**: Plan of Operation
19) **PPP**: Public Private Partnership
20) **PWD**: Public Works Department
21) **UAV**: Unmanned Aerial Vehicle

1.6 Technical Terms

The technical terms related to the Guideline are defined as follows. These definitions are mainly referred to IRC:SP:48-1998 "Hill Road Manual".

<u>Reconnaissance, Survey and Trace Cutting</u>

1) **Reconnaissance:** is a preliminary and usually rapid, examination or survey of a region in reference to its natural features, or other local conditions to determine the location of a proposed highway or other work.
2) **Trace cutting:** is the footpath of prescribed width made along the proposed alignment for facilitating detailed survey, collection of data etc.

<u>Geometrics</u>

3) **Bridle Road:** is provided in border areas and is able to connect the isolated villages each other. It is generally called as a border track or village track.
4) **Camber:** is the convexity given to the cross section of the surface of the carriageway to facilitate drainage.
5) **Crossfall:** is the fall at right angles to an alignment given to the surface of any part of a roadway. It may be expressed as ratio of vertical to horizontal or equivalent percentage.
6) **Curvature** (degree of): is the angle in degrees subtended at the centre of a circular arc by a chord of a given length, usually 30 m.
7) **Curve horizontal:** is the curve in plan to change the direction of the centre line of a road.
8) **Curve transitional:** is a curve whose curvature goes on changing at a certain rate from one radius to another radius for giving smooth change of direction of road.
9) **Curve vertical:** is a curve in the longitudinal section of a roadway to provide for easy and safe change of gradient.
10) **Curve compound:** is a curve consisting of two or more arcs of different radii curving in the same direction and having a common tangent at the point or points of junction.
11) **Curve reverse:** is a curve consisting of two arcs of the same or different radii curving in opposite directions and having a common tangent at the point of junction.

12) **Gradient** (incline or grade)**:** is the rate of rise or fall with respect to the horizontal along the length of a road expressed as a percentage or as a ratio or in degrees.

13) **Gradient ruling:** is a gradient which in the normal course must never be exceeded in any part of a road.

14) **Gradient limiting:** is a gradient steeper than the ruling gradient which may be used in restricted lengths where keeping within the ruling gradient is not feasible.

15) **Gradient exceptional:** is a gradient steeper than the limiting gradient which may be used in short stretches only in extra-ordinary situations.

16) **Hairpin bend:** is a bend in alignment resulting in reversal of direction of flow of traffic. A bend may be for reversing road direction on same face of hill slope.

17) **Ruling minimum radius of a curve:** is the minimum radius of curvature of the centre line of a curve necessary to negotiate a curve at ruling minimum design speed.

18) **Absolute minimum radius of a curve:** is the minimum radius of the centre line of a curve necessary to negotiate a curve at absolute minimum design speed.

19) **Roadway width:** is the sum total of carriageway width and shoulder width on either side. It is exclusive of parapets and side drains.

20) **Road lane width:** refers to the width of carriageway of the road in terms of traffic lanes. Single lane 3.75 m, intermediate lane 5.5 m and double lane 7.0 m (7.5 m with raised curbs), multilane 3.5 m per additional lane.

21) **Sight distance:** is the distance along the road surface at which a driver has visibility of objects, (stationary or moving) at a specified height, above the carriageway.

22) **Slope:** is the inclination of a surface to the horizontal expressed as one vertical linear unit to the number of horizontal linear units.

23) **Super elevation:** is the inward tilt or transverse inclination given to the section of a carriageway on a horizontal curve to reduce the effects of centrifugal force on a moving vehicle. Super elevation is generally expressed as a slope.

Formation

24) **Cliff:** is a high, steep or over-hanging mass of rock.

25) **Cut and fill:** is a term used to describe any section of earthwork which is partly in cutting and partly in filling.

26) **Embankment:** is an earthwork raised above the natural ground by the deposition of material to support construction at a higher level.

27) **Escarpment:** is a steep slope or long cliff resulting from erosion or faulting and separating two areas of different elevations.

28) **Formation width:** is the finished width of earthwork in fill or cut.

29) **Pass:** is a narrow space between mountain peaks that can be used as a way through or on which one can travel.

30) **Passing place:** is an area provided on the side of the road at convenient locations to facilitate crossing of vehicles approaching from the opposite direction and toe aside a disabled vehicle so that it does not obstruct traffic.

31) **Precipice:** is an extremely steep high face of a cliff or mass of rock.

32) **Road land width** (also termed the right of way)**:** is the land acquired for road purposes.

33) **Rock:** is natural accumulation of mineral matter in earth's crust or upper mantle consisting of at least two crust minerals.

34) **Rock, hard:** covers any rock, excavation of which involves intensive drilling and blasting. This can stand vertical or even over-hanging cut depending on the type/mass and dip of the rock.

35) **Soft rock:** comprises of soft varieties of rock such as lime stone, sand stone, laterite, conglomerate or other disintegrated rocks which can be excavated by crow bars and/or pick axes or mechanical excavators normally without use of blasting.

36) **Rock, dip of:** is the angle with which the rock is dipping against horizontal plane.

37) **Rock, fault in:** are rock fractures along which the opposing blocks of rock have moved or moving.

38) **Saddle:** is a saddle shaped depression in the ridge of a hill.

39) **Valley:** is an elongated low land between ranges of mountains or hills often having a river or stream running along the bottom.

Route Selection

40) **Base connection:** is one of the concepts for the development of road networks. This concept has been firstly introduced in Buchanan Report (1963), and widely recognized as a basic idea of the road planning. In order to realize this concept, performance target values, such as travel speed and level of service, are set on the basis of the road types in the United States (AASHTO, 2011) and Japan (MLIT, 1992).

41) **Control point:** is an item which road administrators have to pay special attention in the route selection. It generally depends on the location of structures affecting the project cost and the number of obstacles, such as landslide-prone areas, topographic situations, ground conditions and etc.

42) **Design service traffic volume:** is a numerical value that is the basis for the road planning. It also provides the basis for determining the width and lane number of roads.

43) **Design speed:** is the basic speed for determining the alignment of roads.

44) **Detailed design:** is generally implemented on a map of scale 1/1,000 to 1/300. The output of the detailed design is the basis of the project implementation.

45) **Outline design:** is generally implemented on a map of scale 1/5,000 to 1/2,500. It compares candidate routes, and thus determine the road centre line and the scale of structures for the detailed design. The output of outline design is used to conduct route survey, topographical survey, geological survey and etc.

46) **Road capacity**: is a capacity of road traffic, i.e. the number of vehicles that can pass through roads.

47) **Route planning**: is generally implemented on a map of scale 1/50,000 to 1/25,000. The output of route planning is used to establish the route where outline design is conducted.

48) **Route selection**: is a process and step of selecting a rational one route out of several candidate routes to connect from one point to another point.

49) **Traffic demand**: is a number of vehicles which try to pass through roads at present and future. It corresponds to the traffic capacity when the traffic capacity of roads is not limited.

Protective and Drainage Works

50) **Back filling**: is the earth or other material used to fill cavity on earth retaining structures such as in culvert trenches and behind the bridge abutments, retaining walls etc.

51) **Box culvert**: is a monolithic drainage structure rectangular in section having clear span less than or equal to 6 m.

52) **Catch pit**: is a pit excavated or a chamber constructed below the normal bed level of a ditch, drain, stream or sewer to trap bed silt and solid matter.

53) **Cascade drain**: is a drain of waterfall along the slope.

54) **Catch water drain**: is a drain excavated on the upper slope of a hill road area to intercept and collect water flowing towards the road, and to lead it to a point where no damage will result to the road or in general it is a drain to catch water flowing to a certain area and drain it off to another area.

55) **Causeway**: is a paved dip in a road across a shallow drainage course, at the bed level.

56) **Culvert**: is a structure used for purpose similar to that of a minor bridge having total linear opening of 6 m or less measured at right angles to faces of abutments.

57) **Drain**: is a conduit or channel, either artificial or natural, for carrying off surplus ground water or surface water.

58) **Erosion**: is the process of removal of matter from the banks of a stream or other surfaces by the action of natural forces like flowing water, wind etc.

59) **Retaining wall**: is a wall constructed to maintain in position material capable of exerting lateral pressure, generally a mass of earth.

60) **Side drain**: is a drain along the side of a road.

61) **Sub-surface drain**: is a drain below the ground surface to drain away sub-soil water.

62) **Toe wall**: is small retaining wall structure at the foot of an earth slope.

63) **Vented causeway**: is a paved dip above the bed level of a stream. It is usually provided with vents to pass water or is a causeway with vents below road level to drain off water.

64) **Weep hole**: is a small opening left through soil retaining structure to drain away percolated water.

Pavement Works

65) **Bituminous concrete** (asphaltic concrete): is a mixture of bitumen, coarse aggregates, fine aggregates and filler material and used as a wearing course without any seal coat. It is also termed as Asphaltic Concrete.

66) **Base course**: is a part of the construction resting upon the sub-base or in its absence the subgrade, through which the load is transmitted to the subgrade or the supporting soil.

67) **Carriageway**: is a portion of the roadway designed and constructed for use of vehicular traffic.

68) **Moisture content**: is the loss of weight expressed as percentage of the dry material, when a soil sample is dried to constant weight at 105°C.

69) **Pavement**: is the structure consisting of superimposed layers of selected and processed materials placed on a subgrade to support the applied traffic loads and distribute them to the soil foundation.

70) **Percolation**: is the slow passage of water through soil or a porous solid under the action of gravity.

71) **Subgrade**: is the top 50 cm of the embankment over the entire formation width, directly supporting the pavement.

72) **Sub-base**: is a layer of material placed between the base course and the subgrade.

73) **Surfacing**: is a wearing coat laid upon a prepared foundation in the form of a continuous surface layer.

Bridges

74) **Bridge**: is a drainage structure, with a total linear opening of more than 6 m erected for carrying traffic across a natural or artificial water course, a railway track, another roadway or any other obstruction.

75) **Ledge**: is a shelf like level projection on rock or mountain.

76) **Submersible bridge**: is a bridge designed to allow normal floods to pass through its vents but allowed to be overtopped during high floods.

Miscellaneous

77) **Avalanches**: is a hurtling of a mass of snow/ice moving down from a height and gathering momentum in the descent which may carry rock fragments or earth from hill slope during movement.

78) **Improvement**: is reconstruction in whole or in part to a higher standard of strength, efficiency or quality.

79) **Landslide**: is earth slips on a large scale.

80) **Maintenance**: is the upkeeping of a construction to a definite standard of efficiency and quality.

81) **Pothole**: is a marked local depression in a surface layer, roughly circular in plan, arising from the displacement or wearing away of material by traffic or other causes.

82) **Slip**: is the local soil movement produced by a mass of soil sliding over a slope.

83) **Subsidence**: is the downward movement of the soil produced by removal or displacement of the underlying strata.

84) **Tunnel**: is a passage through a hill to be used as a road, rail track or water channel.

1.7 References

The references of the Guideline are listed as follows.

1) AASHTO: A Policy on Geometric Design of Highways and Streets, AASHTO Green Book, 2011.

2) Buchanan, C.: Traffic in Towns, 1963.

3) Endo, S.: Alignment Design of Hill Roads, 1986 (in Japanese).

4) Indian Roads Congress: IRC:37-2018, Guidelines for the Design of Flexible Pavements.

5) Indian Roads Congress: IRC:52-2019, Guidelines for the Alignment Survey and Geometric Design of Hill Roads.

6) Indian Roads Congress: IRC:56-2011, Recommended Practices for Treatment of Embankment and Roadside Slopes for Erosion Control.

7) Indian Roads Congress: IRC:64-1990, Guideline for Capacity of Roads in Rural Areas.

8) Indian Roads Congress: IRC:SP:19-2001, Manual for Survey, Investigations and Preparation of Road Projects.

9) Indian Roads Congress: IRC:SP:30-2009, Manual on Economic Evaluation of Highway Project in India.

10) Indian Roads Congress: IRC:SP:42-2014, Guidelines on Road Drainage.

11) Indian Roads Congress: IRC:SP:48-1998, Hill Road Manual.

12) Indian Roads Congress: IRC:SP:50-2013, Guidelines on Urban Drainage.

13) Indian Roads Congress: IRC:SP:73-2018, Manual of Specifications and Standards for Two Laning of Highways with Paved Shoulder.

14) Indian Roads Congress: IRC:SP:84-2019, Manual of Specifications and Standards for Four Laning of Highways.

15) Indian Roads Congress: IRC:SP:108-2015, Guidelines on Preparation and Implementation of Environment Management Plan.

16) Indian Roads Congress: IRC:SP:116-2018, Guidelines for Design and Installation of Gabion Structures.

17) Indian Roads Congress: HRB SR No.15, Special Report, State of the Art, Landslide Correction Techniques.

18) Japan Road Association: Commentary and application of road structure ordinance (in Japanese).

19) Japan Road Association: Specifications for Highway Earthwork (in Japanese).

20) Ministry of Land, Infrastructure, Transport and Tourism: Wide Area Highway Development Plan, 1992 (in Japanese).

21) ZENNAMA: Concrete Pavement Q&A, Q-0103 What is difference between asphalt pavement and concrete pavement? (in Japanese).

CHAPTER 2 SURVEY

2.1 General

This chapter presents the survey work in fixing alignment of hill roads on the basis of IRC:SP:48-1998 "Hill Road Manual" and Japanese practical experiences of existing hill road projects. The survey methods presented in this chapter are mainly used before determining the final centre line of roads. For other survey methods used for detailed design of road structures such as slope protection, embankment, tunnel and bridge, the readers are recommended to refer to other guidelines developed in this technical cooperation project.

The requirement of the road is decided based on factors such as administrative, developmental, strategic, other needs and the obligatory points to be connected by roads. Control points between obligatory points are governed by saddles, passes, valleys, river crossings, vertical and over-hanging cliffs, forest and cultivated land and other natural features like escarpments, slide-prone, avalanche-prone and other unstable areas. The control points are usually determined by the appropriate technical authority.

In order to explore the possibility of various alternative alignments, preliminary investigation should start from the high obligatory or control summit points and proceed downwards. The alignment finally selected linking the obligatory and control points should fit in well with the landscape. The aim should be to establish a safe, easy, short and economically possible line of communication between the obligatory points considering the physical features of the region and traffic needs along with least disturbance to the eco-system. Ideal road alignment is the one which will cause the least overall transportation cost taking into account the costs of construction, maintenance, and recurring cost of vehicle operation.

The route should avoid the introduction of hair-pin bends as far as possible. However, if such a provision becomes inevitable, the number of hair-pin bends should be reduced to absolute minimum and the inevitability of each hair-pin bend should be recorded in the reconnaissance report. Further, the bends should be located on stable and flat hill slopes, and their location in valleys should be avoided. Also, a series of hair-pin bends on the same face of the hill should be avoided.

Economy in operating cost of transport vehicles is achieved by adopting easy grades, minimizing rise and fall and by following a direct line as far as possible between obligatory points. Although shortest distance is an important factor, it may have to be sacrificed, at times, in order to obtain easy curvature and gradients, to avoid prohibitive cuts or fills and long river crossings. Even a longer road length to ease gradient and curves may result in a more economical operating cost.

2.2 Contents of Survey for Hill Roads

According to IRC:SP:48-1998 "Hill Road Manual", procedures from the initial survey to fixing the final alignment of hill roads should be conducted in the following sequence.

(1) Reconnaissance

(2) Ground Survey

(3) Determination of Final Centre Line

(4) Final Location Survey

To facilitate the survey team in the tentative selection of alternative alignments for subsequent detailed ground reconnaissance, it will be advisable, if economy of the project permits, to take advantages of advanced techniques, such as aerial survey, photogrammetry and remote sensing. Several advanced survey techniques for the road planning stage are shown in Appendix 3.

2.3 Reconnaissance

2.3.1 General

Once the obligatory points are known, the next step will be to undertake reconnaissance survey in the following sequence.

(1) Study of topographical survey sheets, geological and meteorological maps and aerial photographs, where available

(2) Preliminary aerial reconnaissance (as against aerial photographs), where practicable

(3) Ground reconnaissance

(4) Final reconnaissance of inaccessible and difficult stretches

2.3.2 Study of Topographical Survey Sheets and Maps

Topographical sheets are available in the scale of 1:50,000, i.e. 2 cm to 1 km, showing towns, villages, rivers and terrain features with altitudes and contour lines at intervals of 20 m. Close study of these sheets and the geological and meteorological maps of the area is essential in order to locate the obligatory and control points and to mark tentatively alternative feasible routes on the topographical sheet for further survey on ground. These studies should be done by senior civil engineers to select tentatively and mark the possible routes on the map keeping in view the guiding principles given in Appendix 1 of IRC:52-2019 "Guidelines for the Alignment Survey and Geometric Design of Hill Roads".

Aerial photographs of the area under survey, if available, to the scale of 1:20,000 to 1:50,000, will supplement the information obtained from topographical maps. With stereoscopic techniques a skilled photo-interpreter can not only gather quantitative data but also obtain significant soil and sub-soil information from such photographs which will be very useful in selecting the alignments.

2.3.3 Aerial Reconnaissance

Aerial reconnaissance will provide a bird's eye-view of the alignments under consideration and its surrounding area. A bird's eye-view of the alignments will be obtained efficiently and inexpensively by utilizing the advanced techniques shown in Appendix 3 of this guideline. These techniques will help to identify factors which calls for rejection or modification of any of the alignments. Final decision about the alignments to be studied in detail on the ground which can be taken up on the basis of aerial reconnaissance.

Where required, this should be done by senior civil engineers who are in charge of that specific project along with other assistants. This aerial reconnaissance is essential to verify the correctness of the details of obligatory and control points indicated in the topographical sheets and also to find out other control points, if any, not shown in the map. Such reconnaissance will confirm the feasibility of the routes for proceeding further with ground reconnaissance. The team doing the aerial reconnaissance will have to carry the following documents and equipment's along with them.

(1) Topographical sheets, where tentative routes are marked along with the details of obligatory and control points obtained on study of maps

(2) Photo mosaics or aerial photographs of the area, if available, with pocket stereoscopes

(3) Binoculars

(4) Altimeters

The aerial reconnaissance party will have to fly over the area covering the possible routes selected from study of maps and aerial photographs. Also, that party should examine the following points making notes of observations.

(1) Correctness of obligatory points as given in the map

(2) Correctness of control points as marked in the map

(3) Existence of any other control points not marked in the map:

a) Major saddles/passes

b) River crossings

c) Slide/slip areas

d) Marshy areas

e) Camping sites

f) Rocky areas

g) Vegetation

The altitudes of various obligatory and control points can also be recorded roughly from the altimeter, taking due consideration of the height at which the aircraft hovers over the required points. On completion of the reconnaissance, the team should do the following procedures.

(1) Selection of various alternative feasible routes

(2) Determination of control points

(3) Preparation of the tentative route maps, if necessary, for taking up ground reconnaissance

With aerial photos for topographic map production, which contain overlapping among photos, are interpreted to obtain topographic features shown as follows.

(1) Landslide topography

(2) Lineaments (which suggest faults or fractured/sheared zones)

(3) Traces of debris flow

(4) Traces of erosion

(5) Geological structure (such as dip slope, which may govern cut slope collapse)

(6) Geological condition and topographic anomalies (which imply potential landslides)

While planning new roads, it is important to consider the above information based on the technical solution towards natural conditions. It should be referred to Chapter 3 of the guidelines for viewpoints during route selection. In addition, one should be referred to other guidelines developed in this technical cooperation for the viewpoints to consider from topographic maps and aerial photographs which are necessary for design of road structures, such as earthworks, tunnels and bridges.

2.3.4 Laser Profiler and Photogrammetry with UAV

Airborne survey with laser profiler provides a detailed digital elevation model (DEM) and can produce exaggerated topographic maps, which can help engineer in spotting problematic topographical/geological conditions. One of the special advantages of laser profiler is high permeability through woods but usually such laser equipment is heavy and expensive.

Contrary, a much cheaper solution with portable UAV and digital camera may provide a detailed digital surface model (DSM). Photogrammetry with UAV has its advantage in density of data; the point cloud obtained by photogrammetry with UAV is much denser than DEM by airborne survey with laser. Thus, detailed structure may be highlighted through data processing of DSM from photogrammetry with UAV. It is, however, often affected by tree canopies of woods. Recently, various attempts are being made to remove effects of tree canopy.

2.3.5 Ground Reconnaissance

When the various alternative routes found feasible, the alternatives are further verified physically in the field by ground reconnaissance to recommend the final route. It consists of general examination of the ground by walking or riding along the probable routes and collecting all essential and available data as per guidelines given in Appendix 1 of IRC:52-2019 "Guidelines for the Alignment Survey and Geometric Design of Hill Roads".

This part of the survey is very important in the selection of the final route and should be carried out by a reconnaissance team headed by an engineer of some experience and associated with the survey right from map study and aerial reconnaissance (preferably not less than an assistant executive engineer) supported and assisted by necessary technical and administrative staff and labour. It will be beneficial to associate a geotechnical engineer or geologist with this work. If necessary, local habitants may also be associated with ground reconnaissance.

2.3.6 Reconnaissance Report

On completion of reconnaissance survey on all the alternative routes a report along with a comparative statement of the alternative alignments in the proforma should be prepared along with the recommendations on alignment and could be submitted to the appropriate authority who ordered the reconnaissance survey. The report should contain a plan on the scale of 1:50,000, showing alternative alignments along with their general profile and rough cost estimate. The senior civil engineer responsible for the area should carry out inspection of the alternative alignments personally. Ground reconnaissance may disclose certain difficult stretches which call for detailed examination. A trace-cut might be made in such sections for inspection. Apart from this, before the alignment is accorded for approval by the competent authority, it may be desirable to have one last round of aerial reconnaissance to resolve any remaining doubts. The reconnaissance report is processed to the competent authority for approval.

2.4 Ground Survey

2.4.1 General

This survey consists of pegging at 20 or 25 m intervals on the route previously selected on the basis of the reconnaissance survey more accurately and at regular and close intervals, cutting a trace 1.0 to 1.2 m wide and running an accurate traverse line along it by taking longitudinal and cross sections of the alignment establishing bench marks at convenient intervals and fixing reference pegs where the direction of the alignment changes. The data collected at this stage forms the basis for the determination of the final centre line of the road. For this reason, it is essential that every precaution is taken to maintain high degree of accuracy. Besides the above, general information to concerning traffic, soil conditions, construction materials, drainage etc., which may be relevant for fixing the design features should also be collected during this phase. The survey team may be similar to that for reconnaissance with supporting staff and equipment.

This survey may be done in the following sequences.

(1) Jungle clearance
(2) Pegging the alignment
(3) Trace cut
(4) Survey
(5) Map preparation

2.4.2 Jungle Clearance

An advance party with required labours and tools should commence clearing the jungle along the selected alignment to provide clear sight distance for three or four ranging pole/levelling staff positions at a time on each direction of the alignment. The party should commence work at least three days before the pegging party starts work. The necessary clearance from forest department as required has to be obtained.

2.4.3 Pegging Alignments

A party consisting of the sufficient personnel with necessary equipment should commence checking grade level, directions and curvature of the alignment arrived at earlier, during the reconnaissance re-fixing the correct alignment and re-pegging the alignment at convenient and workable distance, two to three days after the jungle clearance has progressed.

The line, grade and direction of the selected alignment should be properly checked and corrected with the levelling instrument and theodolite with more details and accuracy. The gradient to be followed at this stage should be easier than the proposed to be achieved on the road by a margin of 20 percent or so.

However, the intervals of the pegs should be 20 or 25 m as per ground and terrain condition. The size of the pegs may be 6 cm diameter or square and 60 cm long out of which 45 cm should be driven into the ground. The indication about the grade should be provided at conspicuous locations so as to be easily visible from a distance. To avoid confusion, the earlier markings made in the trees or roads or poles will have to be removed or erased once the corrected and revised makings are ascertained and displayed.

2.4.4 Trace Cut

A party consisting of the sufficient personnel, should carry cut the trace out along the selected alignment and follow the pegging party.

Trace cut will be about 1.0 m wide track cut along the selected alignment to facilitate access to the area for inspection and survey. It may not be possible to cut a trace where the pegged route traverse precipices and may, therefore, be detoured by cutting the trace either along the top or bottom periphery of these areas.

2.4.5 Survey Procedure

The survey should cover a strip of sufficient width taking into account the degree and extent of cut/fill, with some allowance for possible shift in the centre line of the alignment at the time of final design. Normally a strip width of about 30 m in straight or slightly curving reaches (i.e. 15 m on either side of centre line) and 60 m sharp curves and hair-pin bends (i.e. 30 m on either side of centre line) should meet the requirement.

Traverse along the trace cut should be run with a theodolite and all angles measured by double reversal method. Alternatively, this can be done by prismatic compass for less important roads. Distance along the traverse line should be measured with metallic tape or chain. It should be noted that these survey works will greatly reduce the costs by switching from conventional surveying with a total station to that with GPS.

No hard and fast rule can be laid down as regards distance between two consecutive transit stations. In practice, the interval will be dictated by directional changes in the alignment, terrain condition arid visibility. The transit stations should be marked by means of stakes and numbered in sequence. These should be protected and preserved till the final location survey.

Physical features such as buildings, monuments, burial ground, burning places, places of worship, pipelines, power/telephone lines, existing roads and railways lines, stream/river/canal crossings, cross drainage structures, etc. that are likely to affect the project proposals should be located by means of off-sets measured from the traverse line. Levelling work includes taking ground levels along the trace cut at intervals of 20 m to 25 m and at closer intervals whenever there are abrupt changes in slope and also establishing bench marks at intervals of 250 m, exceptionally 500 m, by running check levels on a closed traverse basis independently. While levelling along the tentative centre line, readings of bench marks should also be taken so as to have a cross check in regard to accuracy of field work. It is particularly important that a single datum, preferably GTS datum, is used.

Cross sections should be taken at intervals of 20 or 25 m (At 10 m intervals for steep terrain) and at points of appreciable change in soil conditions. While taking cross sections, soil classifications should also be recorded. At sharp curves and difficult locations, detailed levelling may be done for the plotting of contours. Interval of contours may be 2 m though this could be varied according to site conditions.

2.4.6 Map Preparation

At the conclusion of the ground survey plan and longitudinal sections (tied to an accurate base line) are prepared for detailed study to determine the final centre line of the road. At critical locations like sharp curves, hair-pin bends, bridge crossings etc., the plan should also show contours at 2 m intervals, so as to facilitate taking final decision. The map of the final road alignment may be prepared, where required, with the help of plain table survey as well.

Scales for the map should generally be the same as adopted for the final drawings. Normally horizontal scale might be 1:1,000 and the vertical scale be 1:100. However, for study of difficult locations such as steep terrain, hair pin bends etc., It may become necessary to have larger scale.

It will be a good practice to do survey work in the forenoon and plotting work in the afternoon so that any doubts arising can be cleared immediately thereafter by ground verification.

2.5 Determination of Final Centre Line and Final Location Survey

2.5.1 Determination of Final Centre Line

Determination of final centre line of the road in the design office involves the following operations.

(1) Detailed study should be done of the plans, longitudinal profile, cross-sections and contours of the final alignment prepared during the ground survey to work out various alternatives for the centre line of the proposed road. Out of these, the best one satisfying the engineering, aesthetic, economic and environmental requirements should be selected as the final centre line. Factors like economy in earthwork, least disturbance to hill slope stability, efficient drainage, balanced cut and fill, requirement of protective works such as retaining/breast walls, etc. should be kept in view while making the final choice.

(2) For the selected final centre line, a trial grade line is drawn taking into account the control points which are established by mountain passes, intersections with other roads, river crossings, unstable areas etc. In the case of improvements to an existing road, the existing levels are also kept in view.

(3) For the centre line finally chosen, study of the horizontal alignment in conjunction with the profile is carried out and adjustments made in both, as necessary for achieving proper co-ordination.

(4) Horizontal curves including spiral transitions are designed and the final centre line marked on the map.

(5) The vertical curves are designed and the profiles are shown on the longitudinal sections.

2.5.2 Transit Survey

The final centre line of the road, as determined in the design office, is translated on the ground by means of a continuous transit (theodolite) survey and pegging of the centre line on the ground as the survey proceeds. All angles should be measured with a theodolite. It will be necessary to fix reference marks, to be pegged along the final centre line for this purpose. These marks should be generally 20 m apart in straight reaches and 10 m apart in curves. To fix the final centre line, reference pillars/control blocks of cement concrete of size 30 cm x 30 cm x 60 cm deep should be firmly embedded in the ground. These should be located beyond the expected edge of the cutting on the hill side. The maximum spacing of reference pillars may be 100 m. The following information should be put down on the reference pillars.

(1) Reduced distance of the reference pillar/block

(2) Horizontal distance of the pillar/block from the centre line of the road

(3) Reduced level at the top of the reference pillar

(4) Formation level of the final centre line of the road.

The reference pillars should be such located that these do not get disturbed during construction. Description and location of the reference pillars should be noted in the field book for reproduction on the final alignment plans. Distance of the reference pillars from centre line of road should be measured along the slope, the slope angle determined with theodolite, and the actual horizontal projection calculated.

The final centre line of the road should be suitably pegged at 20 m or closer Intervals. The pegs are intended only for short period for taking levels of the ground along the centre line and the cross-sections with their reference. In the case of existing roads, paint marks may be used instead of pegs. Distance measurements along the final centre line should be continuous, following the horizontal curves, where these occur. At road crossings, the angles which the intersecting roads make with the final centre line should be measured with the help of a transit theodolite.

2.5.3 Detailed Levelling

To establish firm vertical control for location, design and construction, bench marks established during the preliminary survey should be re-checked and where likely to be disturbed during construction re-established at intervals of 250 m (but not more than 500 m), and at or near all drainage crossings.

2.5.4 Longitudinal Sections and Cross Sections

Levels along the final centre line should be taken at all pegged stations and breaks in the ground. Cross-sections should be taken at 20 m intervals. In addition, cross-sections should be taken at points of beginning and end of spiral transition curves at the beginning middle and end of circular curves, and at other critical locations. All cross sections should be with reference to the final centre line, extend normally up to the right-of-way limits and show levels at every 2 to 5 m intervals and all breaks in the profile.

Centre line profile should normally be continued at least 200 m beyond the limit of the road project. This is intended to ensure proper connecting grades at both ends. With the same objective, profile along all intersecting roads should also be measured up to a distance of about 150 m. Further, at railway level crossings, the level of the top of the rails, and in the case of subways the level of the roof, should be noted. On existing roads, level should be taken at all points of intersection in order to help fix the final profile.

2.5.5 Proper Protection of Points of Reference

The final location survey is considered complete when all necessary data and information are available and ready for the designer to be able to plot the final profile and prepare the project drawings and detailed estimate. Among other things, field notes should give a clear description and location of all the bench marks and reference points. This information should be transferred to the plan drawings so that at the time of construction, the centre line and the bench marks could be located in the field without any difficulties.

At the time of execution, all construction lines will be set out and checked with reference to the final centre line established during the final location survey. It is important, therefore, that not only all the points referring the centre line are protected and preserved but these are so fixed at site that there is little possibility of their being disturbed or removed till the construction is completed.

Once the survey and fixing of alignment having been done, the stage has been reached to design the roads.

2.6 Other Surveys

2.6.1 General

Before and after the final centre line is determined, other surveys shall be conducted on a flexible basis according to the place where the road may be installed. Several examples of other surveys are described in this section.

2.6.2 Meteorological Survey

Meteorological observations are carried out in many organizations in India for the purpose of preventing and reducing disasters due to weather, securing traffic safety and proactively using for agriculture and other industries. While social life and industries are diversifying, the disaster due to weather changes, the influence of weather on social and economic activities is increasing, and weather observation will increase its importance, and meteorological observation will increase its importance and in the future.

Meteorological observations have been developed through advancement in science and technology, and engineers can continuously observe a wide range of weather using remote sensing technology such as weather radar and meteorological satellites. Meteorological instruments that directly measure weather used for ground weather observation and high-altitude weather observation are also advanced. In the weather observation, meteorological observation progresses, and together with computerization of society, it is becoming possible to collect and process data from a large number of observation stations using a communication line from a remote place and use it. In such an observation system, in order to maintain observation accuracy, it is necessary to maintain the equipment to be used, maintain the observation environment, quality control of observation data, etc., in addition to select the meteorological instruments to be used.

2.6.3 Hydrological Survey

In case of prevention of the influence on the surrounding water environment and application of the groundwater conservation method, it is necessary to grasp the actual condition of the hydrological environment, forecast the influence of the hydrological environment and formulate a countermeasure at the preliminary survey stage and so on. In order to do that, it is important to first understand the hydraulic geological structure regulating the flow of the groundwater and the groundwater flow mechanism.

In the hydrological survey, it is necessary to understand the purpose of the investigation while taking the construction stage into consideration, and to deal with the local conditions in detail. In addition, it is necessary to consider the progress of construction stage, the current amount of spring water, problems on construction, etc. and to assume the influence on construction of water. And it is also necessary to assume countermeasures corresponding to pre-construction, under-construction, and post-construction. There are several types of hydrological survey as follows.

2.6.3.1 Water Quality Survey

Generally, in water quality survey, indoor analysis will be done by collecting the target precipitation, river water, groundwater including spring water and so on from the site.

The purpose of the water quality survey is roughly divided into the following two points.

To decide the suitability for purpose of use (drinking, industrial use, etc.)

To understand the wide groundwater flow system

In the planning of hill roads, the water quality survey is mainly conducted for the second purpose. The Water quality survey aims to grasp the wide area groundwater flow system, and has ion component analysis and isotopic analysis. Based on these analyses, the flow condition of the groundwater is investigated to estimate the source and estimate of the generation.

2.6.3.2 Spring Water Site Survey

In spring months, water precipitation and others penetrated into the basement and reappeared again on the ground through various routes. The spring water site survey is a survey to understand the range condition of the spring water site, the amount of spring water, the quality of the spring water, etc. by performing a field survey.

The spring water site survey is mainly performed for the following three purposes.

Preliminary examination of spring water from cracks which become a problem in tunnel construction

Survey on range of groundwater level that causes landslide and slope collapse

Basic survey on understanding of water circulation in the area for the purpose of conservation and management of groundwater

2.6.3.3 Seepage Flow Survey

On hill roads, it cannot be evaded the groundwater issues when planning and constructing structures under the ground. For example, in the construction of a tunnel, it is necessary to estimate the amount of discharge and seepage from the mountain and consider the countermeasure method. On the other hand, in urban development, it is necessary to care so that the spring water in the park does not wither, and also necessary to evaluate the possibility of ground subsidence due to the lowering of the groundwater level. The problems of groundwater are very diverse. Groundwater is the water flowing through the underground and it is difficult to confirm the stream. In recent years, however, seepage flow analysis which reproduces the flow of groundwater and evaluates the future condition has also been developed.

2.6.3.4 Geological Survey

Geological survey will be performed to explore the underground structure (geology) for academic purposes and road construction projects and so on. Usually, it refers to a survey based on the observation of outcropping of rock/soil. On the other hand, in a broader sense, it includes geophysical survey using gravimeter and seismic wave, boring survey, remote sensing and so on.

Before performing an investigation in the field, it is common to perform a preliminary survey first. For the preliminary survey, there is documentary searching by geological maps and papers in neighbouring areas, analysis by aerial photographs, satellite images and topographic maps. Next, in the field survey, it will be started with determining the survey route based on the information collected by the preliminary survey and finding outcrops. At the outcrop, observe the geological formations and rocks, and measure the surface and tilt of the fault using clinometer. After that, record the results of the survey on the field note and the route map. Then, based on the results of the geological survey, it will be created boring logs and geological maps.

2.6.4 Material Survey

The material survey of soil and materials along hill roads will be picked up to establish the condition of subgrade, and identify suitable materials for the construction of embankment, subgrade, sub-base, base-cause and other system of the road pavement. Another purpose of the survey will be to determine the engineering properties of the materials, which are to be used during the execution of the project. The engineer has to carry out extensive surveys for other materials such as aggregates and sands for civil and structural works.

2.6.5 Environment Survey

Environment survey will be performed with the aim to collect materials to understand the impact on the natural environment by hill road projects.

In the environment survey, it will be investigated the phases of floras/faunas that live there. For important species, such as protected species, designated by endangered species in laws or regulations, it is necessary to investigate the habitat and growth condition and the environment in detail. These survey results will be materials for considering and forecasting assessment results of environmental impact, project plans and environment conservation measures.

The specific contents of the environment survey include observations using telescope surveying, animal dung, footprints and plants, etc. for animals and plants that live in various places of the hilly area. Additionally, environment surveyors will investigate existing materials and understand the material and where it is breeding. In addition, when the terrain is going to be altered by road construction, it is necessary to consider measures for maintaining the natural environment such as transplantation.

In recent years, attention has been paid to the conservation and regeneration of various natural environments, but the proliferation of exotic organisms and agricultural damage caused by wild animals are also problems. Environmental survey is positioned as the first-step in solving these problems.

CHAPTER 3 PLANNING

3.1 General

This chapter presents the planning of hill roads on the basis of IRC:SP:48-1998 "Hill Road Manual" and Japanese practical experiences of existing hill road projects.

The planning of roads in hill areas is much different from plains. Villages are small and scattered in valleys and over slopes of numerous hill ranges located at different altitudes. These cannot be connected by straight roads as in plains. Alignment of roads has thus to be circuitous and is primarily governed by topography.

In hilly areas, road links should be provided on the basis of cluster or group of villages as far as feasible because the population of each village may be very low. Villages located within a radius of 1.6 km and having an altitude difference of not more than 200 m can be considered as one cluster or group. Isolated villages, having population of more than 500 should be provided with an all-weather link road. For a cluster of villages of population less than 500, a selective approach of an all-weather road within 5 km from the village may be considered to start with. Where funds do not permit construction of regular motor road, road may be constructed for light vehicular traffic to link villages.

Due to topographical constraints and location of small isolated villages, it may not be possible to connect all villages with motorable roads. However, for the overall development, there is a need to connect all villages and production centres with some means of communication. The isolated villages/habitations can be connected by bridle roads after bringing them within 2 to 3 km of a motorable road, with an altitude difference of, say, not more than 200m. Gravity type aerial cableways can also be provided for cheaper and easier transportation of produce to road-head from such isolated habitation, wherever necessary.

As in the rest of the country, roads in hill areas are also classified as National Highways, State Highways, Major District Roads, Other District Roads and Village Roads according to specifications, traffic needs, socio-economic, administrative or strategic considerations. However, from topographical considerations, these can broadly be divided into Arterial roads and Link roads. Arterial roads are trunk routes and can be further divided into Major valley roads and inter-valley roads. While former run in major valleys along rivers/streams or in some cases, depending upon the topography, near to the ridge line, the latter traverse through different valleys, connecting one major valley to another either running near to the ridge line or across slope of hill ranges, rising from one valley to the ridge and going down to the next valley and so on, connecting en route a number of villages to market or administrative centres. Arterial roads will include National/State Highways and Major District Roads. Link roads take off from Arterial roads to link villages/production areas in small/sub-valleys. These will comprise Other District Roads and Village Roads.

3.2 Priority Strategies

The priority strategies of hill roads should be described as follows.

(1) Village connectivity as per criteria shown in 3.1. For hamlets of villages located away from main village, connection may be provided by pathways and foot bridges.

(2) Upgrading of existing unsurfaced roads. Such roads can be used only as fair-weather roads with limited level of service. These roads require to surfacing and providing with cross-drainage works for serving as an all-weather road connection.

While deciding priority for upgradation of the existing unsurfaced road length vis-a-vis new connections, the thrust should be for providing new connections, unless all-weather route is essential for the traffic needs.

On the other hand, the concept of a hierarchical road network was introduced in Buchanan Report (1963), and is widely recognized as a basic idea of the road planning. In order to realize the theory, in the United States (AASHTO, 2011) and Japan (MLIT, 1992), performance target values such as travel speed and level of service are calculated for each road hierarchy. An example of road hierarchy in Japan is shown in Appendix 1.

3.3 Traffic Demand

The design daily traffic volume used for the planning of hill roads is an important issue as it is difficult to set reliable target values for years. In general, it is considered to be about 20 years for important hill roads because it is difficult to predict the long-term change in traffic volume. This policy is considered to be reasonable from the viewpoint of the durability of road structures and economical perspective.

Meanwhile, the target year and traffic demand of hill roads often needs to respond to the growth of traffic volume for a long time because the target year generally becomes long in many cases even for arterial roads. As for the method of forecasting traffic demand and economic analysis, IRC:SP:30-2009 "Manual on Economic Evaluation of Highway Project in India" and IRC:SP:108-2015 "Guidelines on Preparation and Implementation of Environment Management Plan" should be referred.

3.4 Road Capacity

Road capacity analysis is fundamental to the planning, design and operation of roads and provides the basis for determining the carriageway width to be provided at any point in a road network with respect to the volume and composition of traffic. It is also a valuable tool for evaluation of the investments needed for future road construction and improvements and for working out priorities between competing projects. Additionally, IRC:64-1990 "Guideline for Capacity of Roads in Rural Areas" contains recommended design service volumes for hill roads. These are shown in Table 3-1.

The capacity of two-lane roads can be increased by providing paved and surfaced shoulders of at least 1.5 m width on either side. Provision of hard paved shoulders results in slow moving traffic being able to travel on the shoulder which reduces the interference to fast traffic on the main carriageway. Under these circumstances, 15% increase in capacity can be expected vis-a-vis the values given in Table 3-1.

Table 3-1 Recommended Design Service Volumes for Hill Roads

Type of Road	Carriageway Width (m)	Design Service Volume (PCU/day)	
		For Low Curvature (0-200 degrees per km)	For High Curvature (above 200 degrees per km)
Single Lane	3.75	1,600	1,400
Intermediate Lane	5.5	5,200	4,500
Two Lanes	7	7,000	5,000

(Source: IRC:SP:48-1998 "Hill Road Manual")

Additionally, the design service volume of two-lane highway for different type of terrain shall be as per the latest guidelines of the MoRTH which is at present specified in circular no. RW/NH-33044/37/2015/S&R(R) dated 26th May, 2016 as given in Table 3-2.

Table 3-2 Recommended Design Service Volumes (Two-lane Highway)

Nature of Terrain	Design Service Volume (PCU/day)
Plain	10,000
Rolling	8,500
Mountainous and Steep	6,000

(Source: IRC:SP:73-2018, "Manual of Specifications and Standards for Two Laning of Highways with Paved Shoulder")

Moreover, the design service volume for different terrain conditions and level of service shall be as specified in Table 3-2.

Table 3-3 Recommended Design Service Volumes (Four-lane highway)

Nature of Terrain	Design Service Volume (PCU/day)	
	Level of Service 'B'	Level of Service 'C'
Plain and Rolling	40,000	60,000
Mountainous and Steep	20,000	30,000

(Note: The definition of PCU is as per IRC:64-1990, "Guideline for Capacity of Roads in Rural Areas")

(Source: IRC:SP:84-2019, "Manual of Specifications and Standards for Four Laning of Highways")

If a hill road runs through sensitive hills witnessing frequent landslide, following specific provisions shall be made for traffic volumes ranging from 3,000 PCUs/day to about 8,000 PCUs/day.

(1) The carriage width shall be of intermediate lane configurations, i.e. of 5.5 m width, with two-lane structures

(2) The passing places may have widths of 2.5 m and 12 m length and these may be provided on alternate sides of the road. The length of the tapered section may be 6 m on either side of their approaches. Accordingly, the length of the passing places may be 24 m inclusive of the tapered length.

(3) As far as possible, efforts shall be made to provide passing places at locations that could be inter-visible or up to a maximum distance of 500 m apart.

(4) They should not be sited on the inside of a left-hand curve of radius less than the appropriate value for the design speed of the road as this can lead to compromise with visibility.

(5) Further, the passing places/ temporary lay-bys should not be sited on the outside of a right-hand curve with a radius of less than the appropriate value

for the design speed of the road as this increases the risk as a fatigued driver may unintentionally enter the passing places/ temporary lay-by at high speed.

(6) Also, drivers approaching a temporary lay-by along the road must be able to see vehicles entering or existing the lay-by for a distance corresponding to the desirable Minimum Stopping Sight Distance for the design speed of the road. Informatory signs shall be erected at appropriate locations for such lay-bys and further necessary markings shall also be provided.

(Source: MoRTH letter No. NH-15017/28/2018-P&M dated 23rd March, 2018)

3.5 Geometric Design and Design Speed

3.5.1 General

Hill roads have mostly to negotiate through difficult topography, inhospitable terrain and extremes of climatic conditions. As such, design of hill roads to predetermined standards, considering importance of safety and free flow of traffic, is necessary so that travel is safe and comfortable. Geometric design standards have been laid down keeping above factors in view.

3.5.2 Basic Principles of Geometric Design

Design criteria of hilly terrain should be applied for those roads located mostly in hilly terrain where stretches of plain/rolling terrain are short and isolated. Similarly, where hilly terrain intervenes only for short and/or isolated stretches in plain/rolling terrain, criteria for such stretches should be as per standards for plain/rolling terrain.

A uniform application of design standards is desirable for safety and flow of traffic. The use of optimum design standards will reduce the possibility of early obsolescence of the facilities likely to be brought about by inadequacy of the original standards.

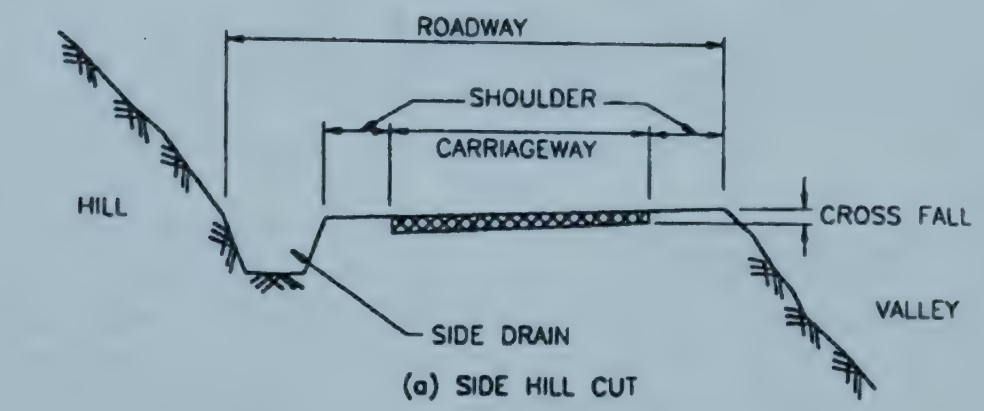
As a general rule, geometric features of a highway except cross sectional elements do not lend to stage construction, particularly in the case of hill roads. Improvement of features like grade and curvature at a later date can be very expensive and sometimes be impossible. It is, therefore, necessary that ultimate geometric requirements of hill roads are kept in view right in the beginning.

Development of cross-section in stages is technically feasible. But this should be decided only after very careful consideration, since hill roads need a lot of protective and drainage works like retaining walls, breast walls, drains of various types and categories etc, consistent with safety and sometimes the road may have to be altogether rebuilt when same is upgraded. If stage construction is unavoidable, better strategy will be to use dry masonry and/or crated. masonry for drains, breast walls, pitching etc, locate the interceptor drain well back at the very start and provide culverts to full width formation/roadway to avoid the need for their widening subsequently. However, road being an important part or rather forerunner of all development activities, stage development will become inevitable over a period of time and as such a decision on this issue should be based on needs for a period of 15 to 20 years or so.

The design standards indicated are absolute minimum. However, the minimum values should be applied only where serious restrictions are placed by technical or economic considerations. General effort should be to exceed the minimum values on safer side to the extent possible. Where the minimum design standards cannot be adopted for inescapable reasons, proper signs should be put sufficiently in advance to inform the road users. The intention should be to provide a road to the user with such geometries which gives safe and reasonably comfortable travel.

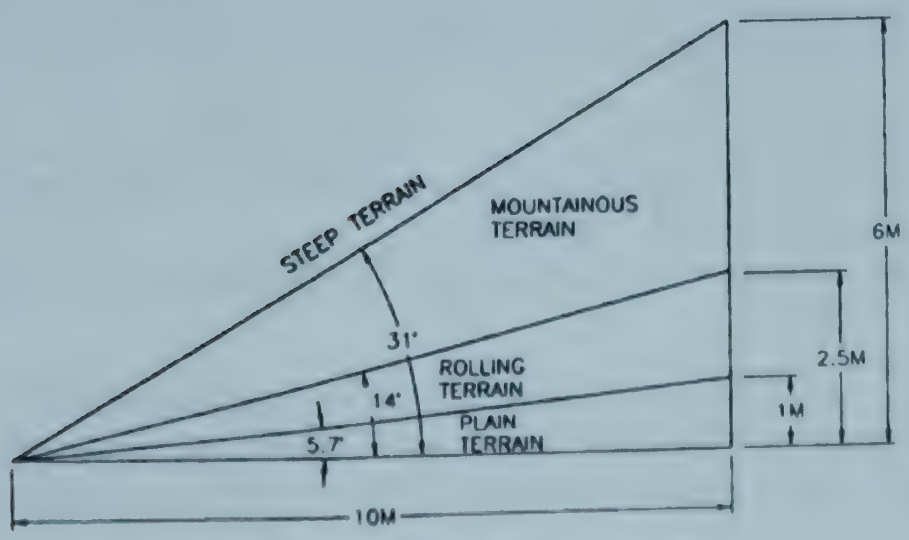
The standards have been classified separately for mountainous and steep terrain. Generally, the standards for steep terrain take lower values of design speed, radii of curve etc. It is likely that in many sectors, the terrain changes from mountainous to steep or vice versa may be within short distances. It is, however, not the intention to change standards frequently. In practice, stretches should be classified as mountainous or steep depending on pre-dominant terrain in the stretch and accordingly standards adopted for that stretch. The same standards should, generally, continue for maximum distance possible/practicable.

Based on IRC:SP:48-1998 "Hill Road Manual", elements of a roadway in hills and plains, classification of terrain and road land widths are depicted in Figure 3-1, Figure 3-2 and Figure 3-3, respectively.



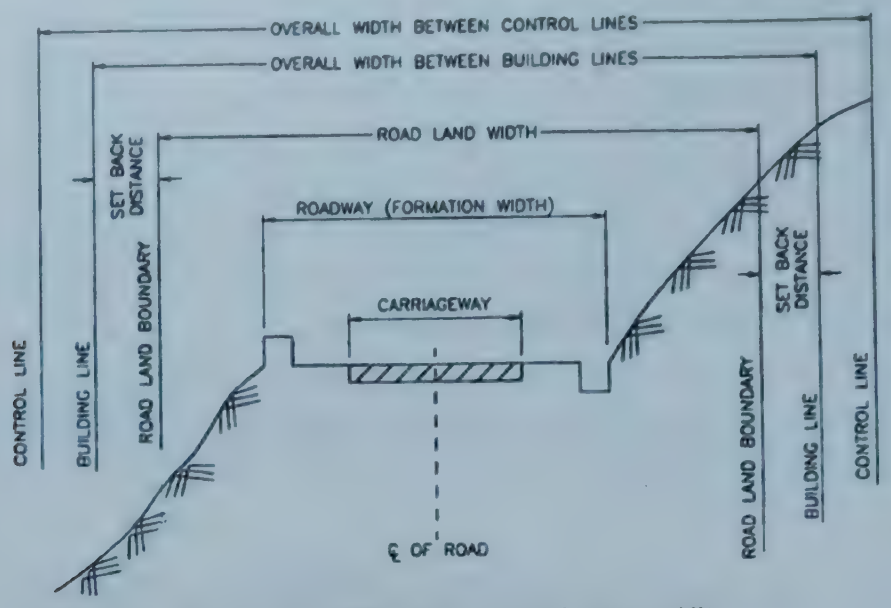
(Source: IRC:SP:48-1998 "Hill Road Manual")

Figure 3-1 Elements of Roadway



(Source: IRC:SP:48-1998 "Hill Road Manual")

Figure 3-2 Classification of Terrain



(Source: IRC:SP:48-1998 "Hill Road Manual")

Figure 3-3 Road Land

3.5.3 Design Speed

The design speed as in IRC:SP:48-1998 "Hill Road Manual" and IRC:SP:73-2018 "Manual of Specifications and Standards for Two Laning of Highways with Paved Shoulder", the design speeds for various categories of hill roads are given in Table 3-4 and Table 3-5.

Table 3-4 Design Speed

Road Classification	Design Speed (km/h)			
	Mountainous Terrain		Steep Terrain	
	Ruling	Min	Ruling	Min
National and State Highways	50	40	40	30
Major District Roads	40	30	30	20
Other District Roads	30	25	25	20
Village Roads	25	20	25	20

(Source: IRC:SP:48-1998 "Hill Road Manual")

Table 3-5 Design Speed (Two-lane and four-lane highways)

Nature of Terrain	Cross Slope of the Ground	Design Speed (km/h)	
		Mountainous Terrain	
		Ruling	Min
Plain and Rolling	Up to 25 percent	100	80
Mountainous and Steep	More than 25 percent	60	40

(Source: IRC:SP:73-2018 "Manual of Specifications and Standards for Two Laning of Highways with Paved Shoulder")

(Source: IRC:SP:84-2019, "Manual of Specifications and Standards for Four Laning of Highways")

Normally, ruling design speed should be the guiding criteria for correlating the various geometric standards. Minimum design speed may, however, be adopted in sections where site conditions including costs do not permit adoption of ruling design speed.

3.6 Route Selection

3.6.1 General

Route selection is a process of selecting "one route" out of several alternative routes in order to connect from one point to another point. It is, however, difficult to quantitatively clarify the inevitability of outcome of route selection. Because the purpose of planning and construction of roads is to satisfy the traffic demand as a part of benefits and welfare for users, planning and construction of roads are implemented for users themselves. When planning new roads, it is important that the following three conditions are considered to be balanced properly. The first is social conditions related to human life. The second is a technical solution toward natural conditions based on topography and geological features. The third is economic conditions. These three conditions are not individual but are related to each other. Because the emphasis differs depending on the statuses, positions and ideas of users, it is complicated and sometimes difficult to satisfy all conditions. For example, road developmental project involves environmental conservation constraints, and there is no simple answer that departs from economic conditions. From these facts, the opinions of users, administrations and residents do not necessarily agree. As mentioned above, various conditions have complicated entanglements. Therefore, the procedure of route selection must select "one route" that satisfy those three conditions better than other alternative routes.

The factors related to route selection are summarized in Figure 3-4. The procedure of route selection involves a complicated relationship as shown in Figure 3-4. However, the scope of route selection narrows down to some extent if the conditions for route selection are clarified based on several factors, such as positions of interchanges and transit zones, results of economic surveys and traffic surveys and reasons of route selection.

In summary, the goal of selecting routes is to find the most appropriate answers through economic considerations in the natural environment. In other words, route selection is to seek a balance between direct and indirect comprehensive benefits obtained together with construction costs commensurate with traffic demand.

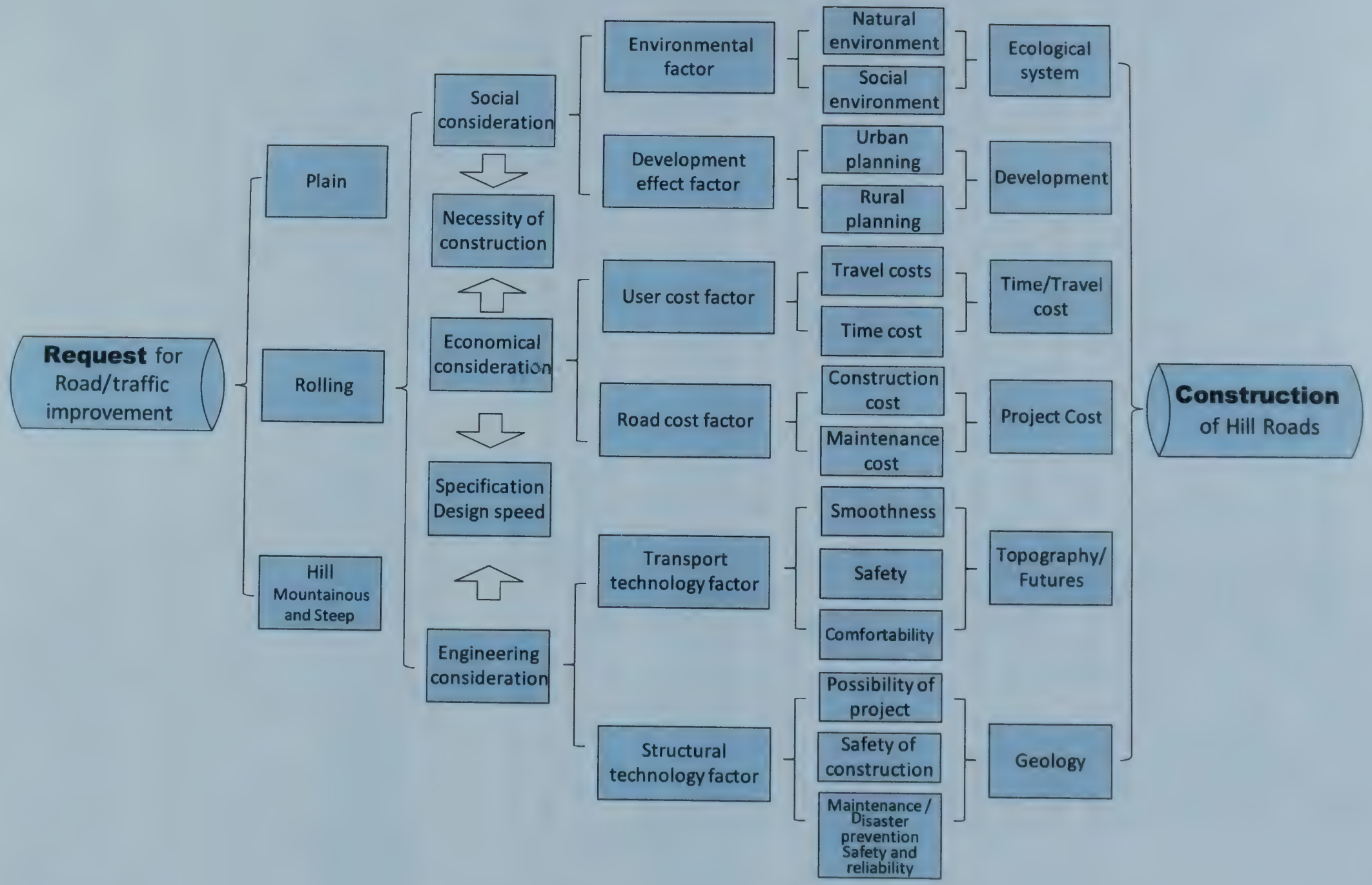


Figure 3-4 Factors Influencing Rout Selections

3.6.2 Policy of Route Selection

Roads are a social infrastructure for carrying things and transporting people from one point to another point. In general, roads should be safe, fast, economical and comfortable for people's transportation.

The most basic principle of the route selection is to connect two points with a short distance. However, in reality, the route in this principle is disturbed by the topography, geology, and other factors, so it is required to consider the parts to escape and turn around as well as how to escape and go around. In addition, it will make modifications to various places so that the linearity arising for escaping and turning around will not rational from the viewpoint of users and from the point of construction.

Therefore, the route selection should not compare many alternative routes from the beginning of planning stage. For example, even if many comparative routes are set, each alternative route has the principles to be safe, fast, economical and comfortable for people's transportation.

3.6.3 Control Points on Route Selection

Conventionally, control points that need to pay special attention in the route selection were mainly the scale and location of structures that affect the project cost, the number of obstacles such as landslide topography and soft ground, and so on. On the other hand, in recent years, areas where buried cultural properties and natural monuments etc. exist and special areas of national parks such as natural environment shifted to those related to conservation of environment or prevention of destruction. However, technical topography and geology issues have not diminished. Among them, the dangers of landslides and slope failures are directly related to the lives of users after use, as well as during construction, so these zones are technically the most important control points for route selection.

When the above control points are categorized into regions, natural conditions can be said to be all in the mountainous regions. In particular, the specific control points that must be taken into consideration in selecting the routes in the mountainous regions are listed as follows.

(1) Topographical and Geological Conditions
   a) Determine the mountain ridge (the peak of the mountain) and the passage point of the mountain pass, i.e. determine the Tunnel location
   b) Determine the passing points of rivers and valleys, i.e. determine the bridge location
   c) Geological problem of areas such as landslide areas, collapsed areas, slope talus, soft ground and other places that ned to be avoided
   d) Large cutting areas or embankment areas that need to be avoided in terms of maintenance or preservation of natural environment

(2) Weather Conditions
   a) In the cold district, to pass the south-facing slope
   b) To avoid frequent fog areas
   c) In the snowy district, to avoid the drifts of snow, avalanche prediction points

(3) Consideration of Related/Existing Facilities
   a) Determination the location of proximity and intersection with arterial roads and railroads
   b) Separation from important structures

(4) Parks, Historical Sites, etc.

a) Important conservation areas to avoid, special protected areas of national parks and natural monuments

3.6.4 Control Points in Planning and Design Stages

During planning and design stage, excellent results can be obtained considering various control points.

(1) Whether the relationship between beginning point and end point is smooth for horizontal alignment and vertical alignment

(2) Whether the scale of horizontal alignment and vertical alignment are well balanced

(3) Whether the horizontal/vertical alignment and the cross sections satisfy the following conditions

a) To keep design speed constant as much as possible

b) To confirm no problem with roadside drains

c) To secure sufficient sight distance

d) To secure travel space of roads

In order to achieve the above goals, it is necessary to plan and design with control of the following matters.

(1) To select horizontal alignment and vertical alignment satisfying the absolute minimum value

(2) To select horizontal alignment and vertical alignment which design speed does not change suddenly

(3) To select horizontal alignment and vertical alignment to be balanced well at the beginning point and end point

(4) Ton confirm no problem in drainage system, sight distance, visual guidance and driver's appearance.

(5) To compare economic conditions

3.6.5 General Scaling, Route Selection and Design Work

The specific work of the route selection and design is able to omit depending on the condition to be given, but the suitable route is generally decided based on the following method.

(1) Route planning: sets up candidate routes with a topographic map of 1/50,000 to 1/25,000 scale. The viewpoint is to establish the range of a passing route where outline design is carried out.

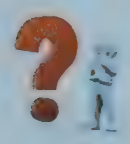
(2) Outline design: is performed on the map of scale 1/5,000 to 1/2,500, compare candidate routes and determine the adequate route. The viewpoint is to determine the road centre line and the scale of the structures to perform the detailed design. Route surveying, topographical/geological survey and so on are carried out by using the outline design.

(3) Detailed design: is performed on the map of scale about 1:1,000 to 1:300, and output is a basis of project implementation.

Regardless of the scale of the topographic map, these tasks require basic knowledge on alignment design and extensive judgment on structural design. Also, as the scale of

the topographic map increases (in other words, when the information of control points become detailed), the contents to be considered becomes more specific.

The outline of the route selection and design is shown in the following reference.



Reference: How do you decide the route of the road?

When deciding the route of the road, it is required to consider sufficiently whether the route is safe and comfortable for traveling, whether the route is economically and technically reasonable and whether the route is suitable for regional land use and environment. The procedure to decide the route is as follows.

Determination of the type of roads:

Designation and certification of roads are conducted according to IRC:52-2019, IRC:SP:48-1998, etc. According to these manuals, the types of roads are determined as one of the followings.

(1) National Highways, (2) State Highways, (3) Major District Roads, (4) Other District Roads and (5) Village Roads.

These are also determined on the basis of the importance, strategy and role in the overall road network.

Determination of road design conditions:

Based on IRC:SP:48-1998, IRC:SP:73-2018, etc. the design speed, lane number, lane width etc. are determined. Once the design speed is set, the design conditions such as the size of horizontal curve and vertical gradient are determined.

Extraction of "Control points":

The accuracy of the control point changes according to the scale of the drawing used for route selection and design as shown in the following table.

Using the survey results such as topographical map, geological map, urban planning map, cultural property distribution map, bio-distribution map, vegetation map, etc., the important area where the roads pass, the location where the valuables are present, the area where the environmental conditions are extremely bad and high project costs are required, etc. are extracted. Such a location is called a "control point". The following control points are considered to be avoided when deciding the route of the road.

(1) Villages, scenic areas, shrines and temples, cemeteries, etc.
(2) Public facilities such as schools, hospitals, government offices
(3) Inhabiting and growing areas of valuable animals and plants
(4) Special designated areas such as important cultural properties and national parks
(5) High mountains, deep valleys, wide rivers, slope collapses, landslides and soft-ground locations.

Route Planning:

First, if you connect between two points, check the control points on the topographic map etc. and check the reference values such as horizontal curves and vertical gradients to determine the route.

Comparison of Routes:

Draw several (3 or 4 alternatives) conceivable routes on the topographic map and compare the routes.

Determination of Optimum Route:

The optimum route is selected based on economic efficiency (project cost), development effect (effects such as time saving, saving of gasoline fee, traffic accident decrease, environmental impact mitigation), workability (difficulty of construction), functionality (safety, convenience such as horizontal and vertical linearity), environmental impact (living environment, topography/geology, impact on the natural environment such as animals and plants).

Reference: Outline of Route Selection and Design

Category	Map Scale	Target	Details of Work		Viewpoints
Route Planning	1:50,000 to 1:25,000	Set up several candidate routes Check whether candidate routes corresponding to design speed is acceptable or not Confirm control points Determine comparable planning zones (belts) including scope of earthwork, bridges and tunnels	Flat Area	Plan several lines (belts) of candidate routes that conform to design standards, assuming socially acceptable route locations, railroads, intersections with arterial roads, and planned locations of long bridges	Judge from a macroscopic overall viewpoint Consider effect of vertical gradient of tunnel on ventilation Conduct field survey by engineers with experience in alignment, structure, geology etc.
			Hilly Area	Based on contour line, assuming average vertical gradient including tunnels/bridges, define approximate horizontal alignment and plan several kinds of candidate routes	
Design	1:5,000 to 1:2,500	Compare and determine candidate routes Compare "Route planning" Design basic horizontal/vertical alignment with consideration of more detailed control points Calculate estimated project cost Understand characteristics of candidate routes	Horizontal Alignment	Consider control points along candidate route, insert horizontal alignment while assuming vertical gradient Adjust horizontal alignment	Secure design standards to ensure level of design Secure balance of alignments combinations Secure continuity of design values Consider alignment for tunnels and long-bridges Consider countermeasures against geological issues Correct alignments based on cross sections at unique topography site Establish basic policies for earthwork/drainage network planning
			Vertical Alignment	Insert vertical alignment taking into consideration of combination of existing ground height of road centre, control points, and horizontal alignment Adjust vertical alignment	
			Cross Section	After confirming above alignments, design cross sections at intervals of 50 to 100 m	
Design	1:1,000 to 1:300	Confirm basic items necessary for project implementation Determine road centre alignment Determine basic policies of various type of structures Calculate /estimate project cost	Horizontal Alignment	Based on outline design, design horizontal alignment based on more detailed control points conditions	Consider of comparison of locations for long-slope, tunnel portal and bridge using detailed topographical data Consider balance of earthworks Others
			Vertical Alignment	Based on outline design, design vertical alignment to minimize earthwork and structure scale	
			Adjustment	Based on cross sections of main parts, adjust horizontal/vertical alignments	
			Cross Section	Design cross sections every 20 m along determined road alignment	

When deciding the route of the road, it is required to consider sufficiently whether the route is safe and comfortable for traveling, whether the route is economically and technically reasonable and whether the route is suitable for regional land use and environment. The procedure to decide the route is as follows.

Reference: Relationship between Road Design and Surveys in JAPAN

Design Phase	Map Scale	Design Target	Topographical Survey	Geological Survey
Conceptual Design	1:5,000 to 1:2,500	- Compare and determine candidate routes - Design basic horizontal/ vertical alignment	- Aerial reconnaissance survey	- Ground reconnaissance - Photo reading

< Purpose of the Survey >

- Understanding the big picture of topography and geology
- Extraction of control points (collapse risk areas, etc.)

Design Phase	Map Scale	Design Target	Topographical Survey	Geological Survey
Preliminary Design	1:1,000	- Determine road centre alignment - Determine basic policies of various type of structures	- Transit Survey - Laser Profiler and Photogrammetry with UAC	- Boring survey at representative locations - Swedish weight sounding test at representative locations - Geophysical exploration

< Purpose of the Survey >

- Understanding of topography and geological composition
- Identifying deformed areas
- Gathering the information needed to determine the form of large structures such as bridges, tunnels, and big slopes

Design Phase	Map Scale	Design Target	Topographical Survey	Geological Survey
Detail Design	1:1,000 to 1:300	- Define the complete specification of the geometry, materials, and tolerances of all the parts - The specification of all the structures complete with preferred suppliers and component designations	- Detailed Levelling - Longitudinal Sections and Cross Sections	- Boring survey - Hydrological survey - Laboratory tests to ascertain physical properties

< Purpose of the Survey >

- Gathering information needed for detailed design of roads, structures, and slopes

3.7 Road Land Width, Roadway, Carriageway and Shoulders

Desirable widths of road land (right of way) for various categories of roads are given in Table 3-6.

Table 3-6 Desirable Road Land Widths

Road Classification	Open Area (m)		Built-up Area (m)	
	Normal	Exceptional	Normal	Exceptional
National and State Highways	24	18	20	18
Major District Roads	28	15	15	12
Other District Roads	15	12	12	9

(Source: IRC:SP:48-1998 "Hill Road Manual")

In order to ensure proper sight distance, it may be necessary to acquire additional right of way over to what is indicated in the Table 3-7.

Notes:

(1) Right of way should be enough to ensure minimum set back of 5 m for building line from edge of road land boundary.

(2) Additional land is required at locations involving deep cuts, high fills and unstable/landslide area.

(3) If the road is planned to be upgraded in the future, land width should correspond to higher class of road.

Width of carriageway, shoulders and roadway for various categories of roads are given in Table 3-7.

Table 3-7 Widths of Carriageway, Shoulder and Roadway

No.	Highway Classification	Carriageway Width (m)	Shoulder Width (m)	Roadway Width (m)
a	National and State Highways			
a-1	Single Lane	3.75	2 x 1.25	6.25
a-2	Double Lane	7.00	2 x 0.9	8.80
2	Major and Other District Roads	3.75	2 x 0.5	4.75
3	Village Roads	3.00	2 x 0.5	4.00

(Source: IRC:SP:48-1998 "Hill Road Manual")

Notes:

(1) The roadway widths are exclusive of parapets (usual width 0.6 m) and side drains (usual width 0.6 m))

(2) In hard rock stretches or unstable locations, where excessive cutting may lead to slope failure, width may be reduced by 0.8 m on two lane and 0.4 m on other roads. Where such stretches are to be provided continuously for long distances, passing places should be provided on such stretch.

(3) On horizontal curves, roadway width should be increased to provide for extra widening at curve.

(4) On roads subject to heavy snow fall, where snow clearance is done over long periods, roadway width may be increased by 1.5 m. However, the requirement of such widening may be examined with reference to ground conditions in each case considering terrain, traffic and other influencing conditions/factors.

The clear roadway width on culverts and causeways (measured from inside to inside of parapet walls or kerbs) should be the same as given in Table 3-6 but for village roads the desirable is 4.25 m.

For bridges, the clear width between kerbs should be 4.25 m for single lane bridges and 7.5 m for double lane bridges.

3.8 Horizontal Alignment

The horizontal alignment should be fluent and blend well with the surrounding topography. A flowing line which conforms to natural contours is aesthetically preferable to one with long tangents slashing through the terrain. The horizontal alignment should be coordinated carefully with the longitudinal profile.

Breaks in horizontal alignment at cross-drainage structures and sharp curves at the end of long tangents/straight sections should be avoided as shown in Figure 3-5.

Short curves give appearance of kinks, particularly for small deflection angles, and should be avoided. The curves should be sufficiently long and have suitable transitions to provide pleasing appearance. Curve length should be at least 150 metres for a deflection angle of 5 degrees and this should be increased by 30 metres for each degree decrease in the deflection angle. For deflection angles less than one degree, no curve is required to be designed.

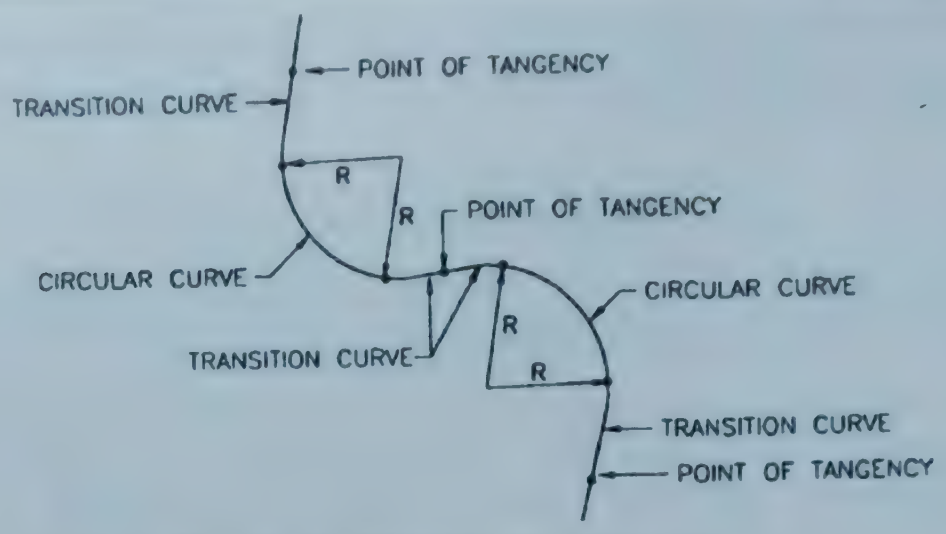
Reverse Curves may be needed in difficult terrain by very sparingly used. It should be ensured that there is sufficient length between the two curves for introduction of requisite transition curves as shown in Figure 3-6.

(a) Break in horizontal alignment at cross drainage structure

(b) Sharp curve at the end of long tangent

(Source: IRC:SP:48-1998 "Hill Road Manual")

Figure 3-5 Bad Alignment



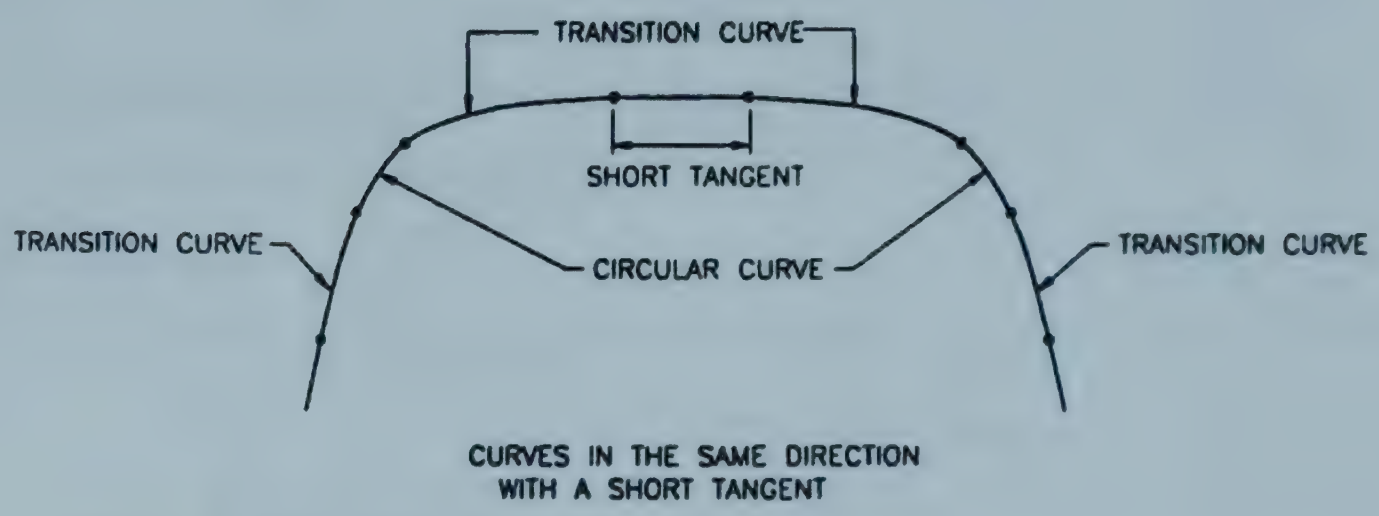
(Source: IRC:SP:48-1998 "Hill Road Manual")

Figure 3-6 Reverse Curve

Curves in the same direction separated by short tangents, known as broken-back curves, should be avoided as far as possible in the interest of aesthetics and safety and replaced by a single curve. If this is not feasible, a tangent length corresponding to 10 seconds travel time must at least be ensured between the two curves as shown in Figure 3-7.

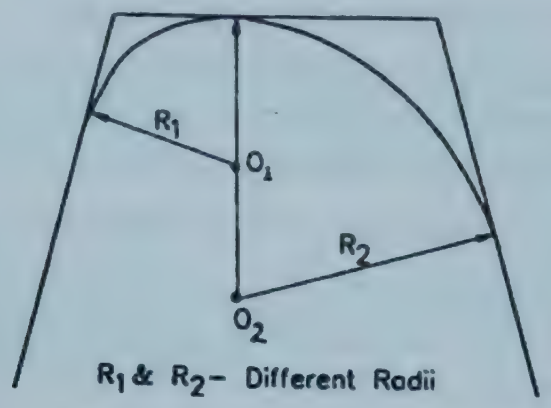
Compound curves may be used in difficult topography but only when it is impossible to fit in a single circular curve. To ensure safe and smooth transition from one curve to the other, the radius of the flatter curve should not be disproportional to the radius of the sharper curve. A ratio of 1.5:1 should be considered as the limiting value as shown in Figure 3-8.

In general, horizontal curves should consist of circular portion of the curve followed by spiral transitions on both sides. Design speed, super-elevation and coefficient of friction affect the design of curves. Length of transition curve is determined on the basis of rate of change of centrifugal acceleration or the rate of change of super-elevation.



(Source: IRC:SP:48-1998 "Hill Road Manual")

Figure 3-7 Broken-back Curve



(Source: IRC:SP:48-1998 "Hill Road Manual")

Figure 3-8 Compound Curve

3.9 Vertical Alignment

3.9.1 General

The Broken-back grade lines, i.e. two vertical curves in the same direction separated by a short tangent, should be avoided due to poor appearance, and preferably replaced by a single curve.

Decks of small cross-drainage structures (i.e. culverts and minor bridges) should follow the same profile as the flanking road section, with no break in the grade line.

Recommended gradients for different terrain conditions, except at hair-pin bends, are given in Table 3-8.

Table 3-8 Recommended Gradients for Different Terrain Conditions

Classification of Gradient	Mountainous Terrain and Steep Terrain more than 3,000m above MSL	Steep Terrain up to 3,000m above MSL
Ruling Gradient	5% (1/20.0)	6% (1/16.7)
Limiting Gradient	6% (1/16.7)	7% (1/14.3)
Exceptional	7% (1/14.3)	8% (1/12.5)

(Source: IRC:SP:48-1998 "Hill Road Manual")

Gradients up to the "Ruling gradient" may be used as a matter of course in design.

The "limiting gradient" may be used where the topography of a place compels this course or where the adoption of gentler gradients would add enormously to the cost. In such cases, the length of continuous grade steeper than the ruling gradient should be as short as possible.

"Exceptional gradient" is meant to be adopted only in very difficult situations and for short lengths not exceeding 100 m at a stretch. Successive stretches of exceptional gradients must be separated by a minimum length of 100 m having gentler/flatter gradient.

The cumulative rise/fall in elevation over 2 km length shall not exceed 100 m in mountainous terrain and 120 m in steep terrain.

3.9.2 Gradient Compensation at Curves

At horizontal curves, the gradients should be eased by an amount known as 'grade compensation' which is intended to offset the extra tractive effort involved at curves. This is calculated by the following formula.

Grade compensation (%) = (30+R)/R

subject to maximum of 75/R where R is radius of the curve in m. Since grade compensation is not necessary for gradients flatter than 4 percent, when applying grade compensation correction, the gradients need not be eased beyond 4 percent.

3.9.3 Vertical Curve

Vertical curves are introduced for smooth transition at grade changes. Convex vertical curves are known as summit curves and concave vertical curves as valley or sag curves. Both these should be designed as square parabolas.

The length of the vertical curve is controlled by sight distance requirements, but curves with greater length are aesthetically better.

Curves should be provided at all grade change exceeding those Indicated in Table 3-9. For satisfactory appearance, the minimum length should be as shown in Table 3-9.

Table 3-9 Minimum Length of Vertical Curves

Design Speed (km/h)	Maximum Grade Change (%) not Required a Vertical Curve	Minimum Length of Vertical Curve (m)
Up to 35	1.5	15
40	1.2	20
50	1.0	30

(Source: IRC:SP:48-1998 "Hill Road Manual")

3.9.4 Gradient control

There are some considerations while doing route selection in Hill Roads. The roads on the slopes of hill roads generally will be large cut-slopes, embankment-slopes and structures such as shown on left side of Figure 3-9. In such a case, it is necessary to separate the upper and lower lines such as shown on right side of Figure 3-9. Such considerations can reduce the size of cut-slopes, embankment-slopes and structures.

Figure 3-9 Gradient Control

3.9.5 Climbing Lane

The horizontal alignment does not affect the performance of vehicles, but the vertical alignment/gradient greatly effects their travel speed depending on the performance of vehicles. Especially for trucks, the travel speed decreases significantly.

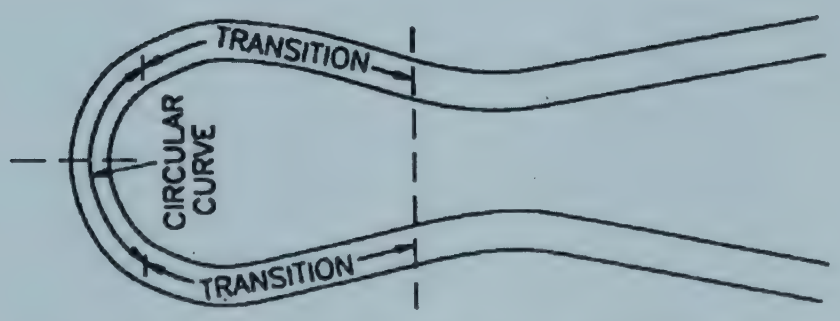
The decrease in the travel speed of the truck obstructs the driving of the passenger vehicle, confuses the driver, and reduce traffic safety. In addition, it causes the traffic capacity of the road to decrease. It is desirable to design a medium vertical gradient and "additional climbing lane" if possible.

3.10 Design Criteria for Hair-pin Bends

Hair-pin bends, where unavoidable, may be designed either as a circular curve with transition at each end, or as a compound circular curve. The following criteria should be followed normally for their design.

Inner and outer edges of the roadway should be concentric with respect to centre line of the pavement. Where a number of hair-pin bends have to be introduced, a minimum intervening distance of 60 m should be provided between the successive bends to enable the driver to understand the alignment smoothly.

Widening of hair-pin bends subsequently is a difficult and costly process. Moreover, gradients tend to become sharper as generally widening can be achieved only by cutting the hill side. These points should be kept in view at the planning stage, especially if a series of hair-pin bends are involved. At hair-pin bends, preferably, the full roadway width should be surfaced. The criteria shown in Table 3-10 should be used for design.



(Source: IRC:SP:48-1998 "Hill Road Manual")

Figure 3-10 Hair Pin Bend

Table 3-10 Design Criteria of Hair Pin Bend

Minimum Design Speed		20 km/hr
Minimum Roadway Width at Apex		
i. National/State Highways		11.5 m for double-lane 9.0 m for single-lane
ii. Major District Roads and Other District Roads		7.5 m
iii. Village Roads		6.5 m
Minimum Radius for Inner Curve		14.0 m
Minimum Length of Transition Curve		15.0 m
Gradient	Maximum	2.5 %
	Minimum	0.5 %
Super Elevation		10.0 %

(Source: IRC:SP:48-1998 "Hill Road Manual")

3.11 Passing Places

Passing places are required on single lane and intermediate lane hill roads to facilitate crossing of vehicles approaching from the opposite direction and to tow aside a disabled vehicle so that it does not obstruct traffic.

Based on the provisions of MoRTH letter No. NH-15017/28/2018-P&M dated 23rd March, 2018, following specific provisions shall be made for traffic volumes ranging from 3,000 PCUs/day to about 8,000 PCUs/day.

(1) The passing places may have widths of 2.5 m and 12 m length and these may be provided on alternate sides of the road. The length of the tapered section may be 6 m on either side of their approaches. Accordingly, the length of the passing places may be 24 m inclusive of the tapered length. The diagram of the passing places is shown in Figure 3-11.

(2) As far as possible, efforts shall be made to provide passing places at locations that could be inter-visible or up to a maximum distance of 500 m apart.

(3) They should not be sited on the inside of a left-hand curve of radius less than the appropriate value for the design speed of the road as this can lead to compromise in visibility.

(4) Further, the passing places/temporary lay-bys should not be sited on the outside of a right-hand curve with a radius of less than the appropriate value for the design speed of the road as this increases the risk as a fatigued driver may unintentionally enter the passing places/temporary lay-by at high speed.

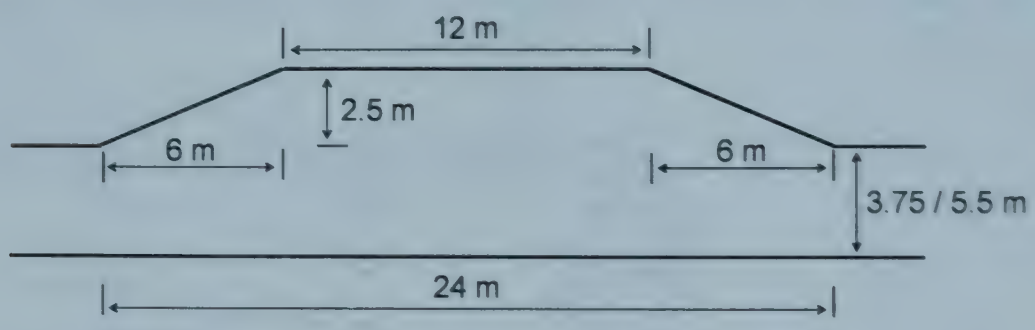


Figure 3-11 Passing Places

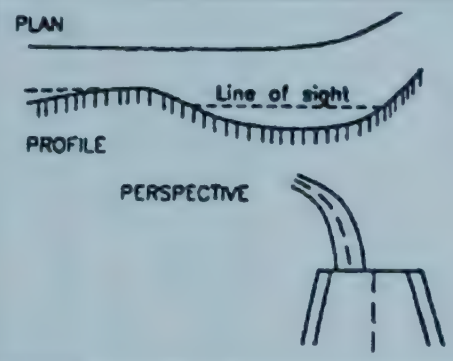
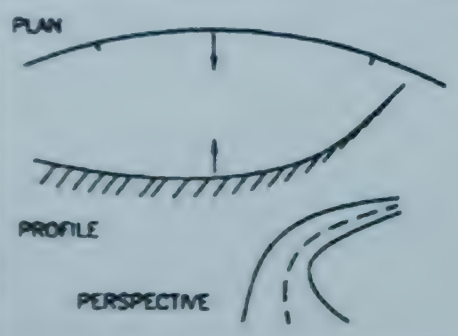
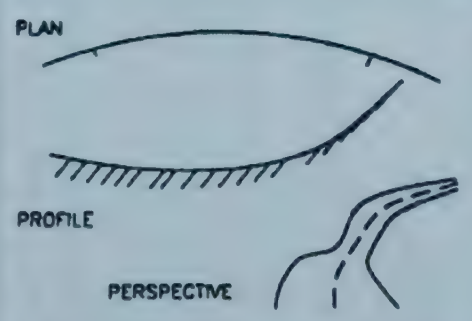
3.12 Vertical Alignments

The overall appearance of a highway can be enhanced considerably by judicious combination of the horizontal and vertical alignments. Plan and profile of the road should not be designed independently but in unison so as to produce an appropriate three-dimensional effect. Proper co-ordination in this respect will ensure safety, improve utility of the highway and contribute to overall aesthetics.

Vertical curvature superimposed upon horizontal curvature gives a pleasing effect. As such the vertical and horizontal curves should coincide as far as possible and their length should be more or less equal. If this is difficult for any reason, the horizontal curve should be somewhat longer than the vertical curve.

Sharp horizontal curves should be avoided at or near the apex of pronounced summit/sag vertical curves from safety point of view.

Some typical cases of good and bad alignment coordination are shown in Figure 3-12.

Good Design Form		Undesirable Design Form	
	(a) VERTICES OF HORIZONTAL AND VERTICAL CURVES COINCIDE. VERTICAL CURVE KEPT WITHIN HORIZONTAL CURVE BRINGS OUT A VERY PLEASING APPEARANCE		VERTICAL CURVE PRECEDES HORIZONTAL CURVE HORIZONTAL CURVE LOOKS LIKE A SHARP KINK. POOR APPEARANCE
	(b) SAME AS (a) BUT INVOLVING A SERIES OF CURVES VERTICES OF HORIZONTAL AND VERTICAL CURVES COINCIDE, PRODUCING A VERY PLEASING APPEARANCE.		HAZARDOUS LEVEL CROSSING (OR ROAD INTERSECTION) AND SHARP HORIZONTAL CURVE ARE OBSCURED FROM DRIVER'S VIEW BY SUMMIT CURVE. DANGEROUS SITUATION.
	(c) SIMILAR TO (b) BUT ONE PHASE SKIPPED IN THE HORIZONTAL PLANE, VERTICES OF CURVES STILL COINCIDE, A SATISFACTORY APPEARANCE RESULTS		HORIZONTAL CURVE IS HIDDEN FROM DRIVER'S VIEW CAUSING A DISJOINTED EFFECT
	(d) PROVISION OF A LONG VERTICAL CURVE COMPATIBLE WITH THE HORIZONTAL CURVE PRODUCES A SMOOTH FLOWING - ALIGNMENT AND A PLEASING THREE DIMENSIONAL VIEW.		SAME AS (d) BUT THE VERTICAL CURVE IS MADE MUCH SHORTER THOUGH THERE IS NO DISCONTINUITY IN PLAN OR PROFILE SINGLY THREE DIMENSION VIEW IS POOR

Sketches showing good and bad alignment coordination (Source: IRC:SP:48-1998, PLATE-7)

Figure 3-12 Sketches Showing Good and Bad Alignment Coordination

3.13 Road Structures

Hill Road is formed mostly by cutting into the hill and thereby disturbing natural stability of slopes. Water courses along the slopes cause erosion affecting road stability. Soil movement along slopes tend to disturb the road formation. All these have to be effectively countered to obtain a stable road by provision of structures to act as retaining, restraining and protective structures. Similarly, safety of traffic also needs structures to be provided on the road. Where the road is aligned along a river bank or a nailah (stream) slope failure and erosion of toe has also to be prevented and valley side slope made stable. This can be achieved by construction of retaining walls, breast walls, parapet walls, railings, edge stones, toe walls, check-walls, river training structures etc.

For details of planning, design, construction, operation and maintenance of structures, such as slope protection, embankment, tunnel and bridge, the readers are recommended to refer to other guidelines developed under this technical cooperation project.

3.14 Pavement

Design of pavement for roads, whether in plains or hills follows the same basic principles like soil and traffic parameters and also climatic considerations and their effects. However, while planning/designing pavement for hill roads, specific aspects relevant to the hill regions like terrain and topographic conditions, extremes of weather conditions, altitude effects etc. should also be duly considered and suitably incorporated in the design so that the pavement is able to perform well for the designed traffic and service life.

Considering various conditions, rigid pavement is not generally recommended for roads in hilly regions. In seismic areas, rigid pavement is liable to severe damages whereas flexible pavement, by its granular composition, can withstand effects of tremors better. Thus, flexible pavement is normally provided on the hill roads. For reference, the characteristics of rigid pavement and flexible pavement are shown in Table 3-11.

Table 3-11 Difference between Rigid Pavement and Flexible Pavement

Item	Rigid Pavement		Flexible Pavement	
Initial Cost	High	• 1.05 - 1.1 • Initial costs are already low in the US, depending on the country	Low	• Cost difference has disappeared due to soaring asphalt unit prices
Life-cycle Cost	Low	• 0.3 - 0.75 • Roads with longer service /maintenance periods have lower life cycle costs	High	• Frequent maintenance and repair of road surface due to rutting and so on.
Endurance Period	20-years	• Design pavement thickness with 20 years of fatigue fracture wheels	10-years	• Design equivalent thickness with 10 years of fatigue fracture wheels
Workability	Not good	• The number of construction machines is small and not widely used	Good	• There are many construction machines according to the size of the pavement
Repairing	Not good	• Less repair frequency, but longer repair period	Good	• More repair frequency, but shorter repair period
Driving Comfortability (short term)	Not good	• Joints installed at short intervals affect drive comfort	Good	• Immediately after completion, there is no joint so it is comfortable to drive
Driving Comfortability (long term)	Good	• Drive comfort is not impaired because the road surface wear and deformation is small	Not good	• Deformation due to rutting (etc.) on the road surface affects drive comfort
Lighting Cost	Low	• 0.7 - 0.8 • Lighting efficiency is good because the road surface is white	High	• Lighting efficiency is poor because the road surface is black
Environmental Performance-1 (fuel efficiency)	Good	• 0.95 - 0.99 • Rolling resistance on road surface is low	Not good	• Rolling resistance due to large deformation of the road surface is high
Environmental performance-2 (temperature)	Low	• About 10-degree lower (summer season in Japan) • Road surface temperature is low because the road surface is white	High	• Road surface temperature due to black surface is high
Environmental performance-3 (noise)	High	• Joints installed at short intervals affect the running noise of vehicles	Low	• Low driving noise due to no joints

(Source: Concrete Pavement Q&A, Q-0103 What is difference between asphalt pavement and concrete pavement?, ZENNAMA)

3.15 Drainage and Cross-Drainage

3.15.1 General

Drainage is one of the most important issues on hill roads from the viewpoints of not only traffic operation and management but also road structures. Collapse of hill roads and its structure is often induced because of the following factors.

(1) Surface water run-off on the road from its surroundings

(2) Rise of groundwater in the surrounding areas

(3) Uncontrolled water flow from seepage or spring of groundwater or outlets or leakage of drainage control of hill road

The weakest point of roads is "water/drainage", and proper drainage is one of the most important tasks in the planning and construction of roads.

Topography of hill generates numerous water courses. This coupled with continuous gradient of roads in hills and high intensity of rain-fall calls for effective drainage of roads. Uncontrolled water is the primary cause of problems like soft surfaces, pot holes, rutting, washed out shoulders, and even failure of complete sections of roadway structures. Prevention of such failures makes roads safer for motorists and pedestrians, reduces maintenance costs and adds immeasurably to the pleasure and satisfaction of the road user. A hill road is good if the degree of drainage achieved is good.

The cost of controlling water is a significant part of total highway construction cost. It is therefore important to plan and develop adequate facilities for drainage and erosion control.

A cardinal rule while planning drainage would be least interference with natural drainage. Ideally, this might be achieved by aligning all roads along ridges or drainage divides. For most roads, however, alignment is already determined by various other obligatory considerations. Minimum interference with natural drainage will mean stable earth face/surface with some kind of vegetative cover preventing erosion and allowing free drainage.

On the hill roads the moisture content in the subgrade is liable to considerable seasonal variation on account of the following points.

(1) Water seepage through the adjacent hill face of the road

(2) Fluctuation in the water-table

(3) Percolation of water through the wearing surface

(4) Transfer of moisture/water vapor through different soil layers

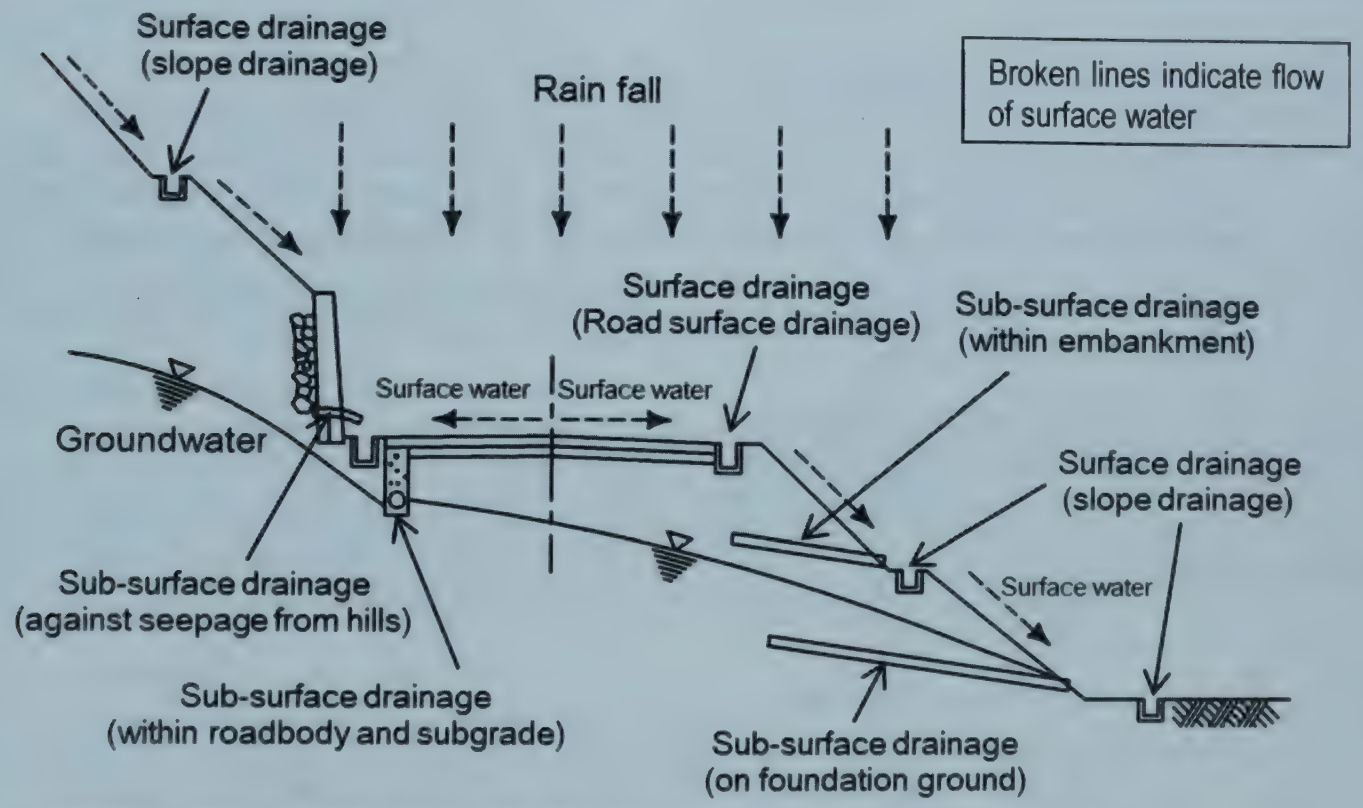
(5) Snow fall and snow accumulation in the area

Water flowing towards the road surface may be diverted and guided to follow a definite path and the flow towards the valley side is controlled so that stability is not affected. This will help in protecting the road bed and pavement. A network of drains helps in confining and controlling flow of water and thus checks adverse effect on road structures. In hill roads, where the surface and sub-soil water run rapidly towards subgrade, interceptor drains would trap the flowing water and prevent it from reaching the road side. In the lower slope i.e. near the pavement, the in-flow of water in side drains will be local only. This has to be intercepted by catch pits which will collect the flow from side drain, reduce velocity and divert the flow to cross drain/culvert for disposal.

When viewed in totality against the back-drop of the hills, the road acts as an interceptor and its longitudinal cut on hill slope obstructs the natural drainage and the road ledge therefore acts as a collection area of all water from hill side. As such adequate drains in the form of catch water drains collecting flow from hill side to bring it to side drain leading to cross drains and further discharge it into natural drainage channels through valley side drain/chutes (if erosion is likely on valley side), are essential for stability of road.

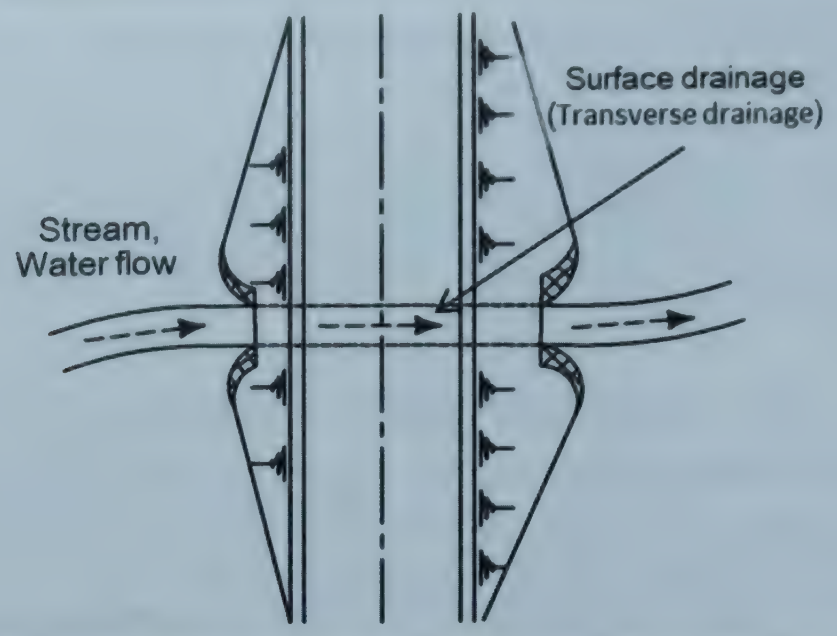
3.15.2 Classification and Purpose of Road Drainage System

During the planning and design of hill roads, the following types of water are targeted for drainage: rain, snow melting, surface water, spring water, and groundwater. To ensure stability of hill roads, before preparing road drainage plan, purpose and function of road drainage facilities should be well understood. Drainage facilities are classified in two categories: surface drainage and sub-surface drainage. Examples of drainage facilities for roads are shown in Figure 3-13 and Figure 3-14.



(Source: Specifications for Highway Earthwork, Japan Road Association)

Figure 3-13 Water and Drainage Relating to Road Structure



(Source: Specifications for Highway Earthwork, Japan Road Association)

Figure 3-14 Water Stream Crossing Roads

3.15.2.1 Surface Drainage

Surface drainage should properly collect all water on the surface of pavement and from its surroundings and smoothly drain such water through road drainage facilities to adjacent water system which can dully accommodate such drained water.

Depending on the targeted water, the following drainage facilities should be properly planned and designed.

(1) Road Surface Drainage
It aims to gather and channelize the precipitated water on the road surface and from the side slopes and nearby land thus to avoid its access to and retention on the road surface. The water collected from the surface of road and the adjacent ground is taken away by side drains and drained into natural water courses nearby.

(2) Transverse drainage
It aims to keep continuity of natural water course which is obstructed by construction of road. In the design, enough capacity should be secured to avoid flooding of the platform and surrounding areas when encountered with high water level.

(3) Slope drainage
This drainage should be applied on both cut and embankment slopes and so designed as to properly collect surface water on the slope to avoid erosion of slope and infiltration of surface water to the ground in the aim of keeping stability of slope. In case a slope failure occurs, as an emergency countermeasure, it can also be deployed to assist stabilization of slopes.

3.15.2.2 Sub-surface Drainage

Sub-surface drainage should be so designed as to release water trapped inside subgrade and pavement layers on hill roads. This is to avoid such unfavourable conditions listed as follows.

(1) Soil resistance against compression drops substantially when its moisture content increases.

(2) Increase in moisture content inside pavement and embankment beyond a limit (e.g. Liquid Limit) results in reduction of load carrying capacity of the road.

(3) Such situation leads early deterioration of pavement and may eventually cause collapse of road structure.

Depending on the locations to be installed, the following sub-surface drainage should be properly planned and designed.

(1) Drainage within road body and subgrade
It aims to maintain a good condition of subgrade and base course by blocking off seepage into subgrade from adjacent areas and lowering groundwater level under the road body or the existing ground. As a reference, specific information is included in IRC:SP:42-2014 "Guidelines on Road Drainage".

(2) Drainage in boundary between cuts and fills
Embankments in the sections including boundaries between cut and fill or having hill on one side and valley/plain on the other side often becomes unstable when spring water from hill side permeates into the embankment. It is particularly easy for water to accumulate in the sections in the boundary between cuts and fills, so sub-surface drainages are necessary in these sections.

(3) Drainage within embankment
It aims to discharge spring and seepage water from embankments in order to keep stability of embankments. Particularly for the embankments in the hilly areas for hill roads, horizontal drainage layers, subsurface drains, and base drainage layers should be implemented regardless of the presence of spring waters or streams. Subsoil drains and horizontal drainage layers are to remove the water that percolates into embankment, and base drainage layers are to prevent water from the existing ground from percolating into embankment.

(4) Drainage on foundation ground
Spring or seepage water from the ground where foundation of embankment is laid often raises groundwater level in the embankment that may destabilize the embankment slope and lead to slope failures. To prevent such situation, in cases where spring water seepage or flow is found from the ground where foundation is laid, proper drains and sand mats should be placed or laid.

(5) Drainage against seepage from hills
The drainage against seepage from hills is described in IRC:SP:48-1998 "Hill Road Manual". Seepage from hill sides in cut sections is a source from where embankment, subgrade, and base/sub-base get soaked. Roads are often damaged in stretches where there is excessive seepage from hills in absence of adequate sub-surface drainage.

3.15.3 Surface Drainage System

3.15.3.1 Hydrological Study of Rain and Snowfall

In order to determine the design capacity of surface drainage facilities, flow volume of water to be drained by such facilities should be well studied. The hydrological studies of rain and snowfall are included in IRC:SP:42-2014 "Guidelines on Road Drainage", IRC:SP:50-2013 "Guidelines on Urban Drainage" and IRC:SP:48-1998 "Hill Road Manual" and hydrological studies for hill roads should follow applicable part in these standards.

Among hydrological studies, there are several formulas to determine the intensity of rainfall. Upon determining the formula, appropriate evaluations should be done after collection of data from actual observational values.

3.15.3.2 Road Surface Drainage

When a hill road is constructed on natural terrain, the waterways are intercepted and hence it is necessary to take measures to divert such water from the road. Additionally, water on the road surface from rain and snowfall has to be disposed of as quickly as possible to prevent the formation of a sheet of water on the road surface out of safety considerations.

Normally the road surface is given a cross-fall and a longitudinal gradient, so that water received on the surface of pavement is collected to the roadside or median drainage equipment. Drainage structures such as side ditches, lined drains, concrete kerbs, and catch-drains are used as road surface drainage equipment. The selection of the type of drains shall be based on the magnitude and duration of flow calculated by the hydrological study of rain and snowfall, and shall not pose any danger to traffic, slopes of cuttings, embankment, pavement or structures. Plan of the road surface drains are included in IRC:SP:42-2014 "Guidelines on Road Drainage", IRC:SP:50-2013 "Guidelines on Urban Drainage" and IRC:SP:48-1998 "Hill Road Manual" and plans for hill roads should follow applicable parts of these standards.

When designing a road surface drainage, it is necessary to consider the effect of the geometric features of the pavement. According to IRC:SP:42-2014 "Guidelines on Road Drainage", the effect of the geometric features of the pavement is summarized as follows.

(1) Longitudinal gradient of the pavement laid
With a view to facilitate quick removal of rain water, longitudinal profile of the road normally is not designed flat. When the road is provided with kerbs, flat surface can result in collection of large quantity of water on the road. To avoid this situation a minimum longitudinal gradient of 0.3 percent is considered essential in most conditions.

(2) Pavement cross-fall or camber
By providing cross-fall or camber to the pavement, the run-off water gets cleared from the surface rapidly. The cross-slope requirement differs for each pavement type. A mild cross-slope is sufficient in dense surfaces like bituminous concrete surface or concrete pavement but open-graded bituminous surfaces and granular/earthen surfaces require relatively steeper cross-slope for facilitating rapid flow. But steeper cross-slope in the case of granular/earthen surface may lead to erosion of surface. The cross-slopes proposed for adoption in Indian roads are given in Table 3-12.

Table 3-12 Proposed Camber/Cross-Fall

Surface Type	Non-Kerbed Roads	Roads with Kerb
Earthen, Gravelled or WBM surface	3 – 5%	–
Thin open graded bituminous surfacing	2.5 – 3%	2.5 – 3%
High type bituminous surfacing	2.0 – 2.5%	2.5%
Cement concrete surfacing	2.0% – 2.5% in case of transverse tine or brush texturing	2.5%
	2.5% – in case of longitudinal tine texturing	2.5%

(Source: IRC:SP:42-2014 "Guidelines of Road Drainage")

3.15.3.3 Transverse Drainage

Whenever streams have to cross the road, cross drainage structures have to be provided. Similarly, water from the side drains is taken across by these cross drains in order to divert the water away from the road to a water course or valley. The concept of transverse drainage is described in IRC:SP:48-1998 "Hill Road Manual".

Normally experience and local practice will be highly helpful in the choice of the appropriate crossing. However, there can be overlapping cases suggesting more than one alternative. In such cases, where doubt exists, it would be worthwhile to evaluate alternatives taking all the above-mentioned aspects into account. For quick selection of promising alternatives, the guidelines given in Table 3-13 are helpful.

Table 3-13 Guidelines for Choice of Cross Drainage Structures for Hill Roads

Type of Structure	Locations where the structure will be found suitable
Ford	Shallow non-perennial stream where maximum depth of flow does not exceed 1.6 m and the period of interruption at one stretch does not exceed 12 hours for ODRs and 24 hours for VRs in hilly terrain. Also, the total period of interruption in a year may not exceed 10 days for ODRs and 15 days for VRs. Suitable for roads in isolated areas carrying very low traffic. Also, for roads in a network where alternative route is available during the rainy season. Low in initial cost and ideal for crossing of men on foot and cattle.
Paved Dip (flush or low-level causeway)	Same as for Sr. No. I except that the traffic on the road may be somewhat higher.
Vented Causeway	Shallow streams having permanent dry weather flow exceeding 0.6 m in depth. The same criterion indicated for Sr. No. 1 as regards interruption equally applies to this case also.
Submersible Bridge	In case where high-level bridge is too expensive to construct.
Culvert	This is a high-level structure having length between abutments up to 6 m. Suitable for narrow streams.
High Level Bridge	Ordinarily high-level bridges are designed to cuter for the maximum possible flood discharge. Situations warranting such bridges are crossings of deep narrow streams or ravines in hilly terrain.
Steel Equipment Bridges (Portable)	Portable steel bridges are quite easy and quick to construct even for emergent needs.
Suspension Bridges	Ideally suitable to bridge long and deep gaps in hilly terrain.
Boat Ferry and Pontoon/Boat Bridge	In case of large streams where it is not economical to provide a bridge. Ferry service or Pontoon /boat bridge may be appropriate.
Other Crossings	Wire rope trolley may be used for remote and unimportant areas.

3.15.3.4 Slope Drainage

The control of the surface water flowing down the slope and the seepage water from slope surface is one of the most important in the stabilization of slopes. The selection, design and construction of appropriate facilities as well as an arrangement of the drainage equipment location allowing practical maintenance is therefore necessary. Slope drainage systems for surface water, groundwater and spring water are presented in Table 3-14. The installation of such drainage equipment on roadside slopes is presented on Figure 3-15.

Table 3-14 Slope Drainage System

Types of Slope drainage	Function
Surface Drainage	
Cut-off Drain (Catch Water Drain)	- Prevention of descending surface water to the slope surface
Berm Drain	- Guidance of rain water on the slope surface to a "Cascade drain"
Cascade Drain (Chute/Flume Drain)	- Guidance of water in a "Cut-off drain" at the top of a slope and in a "Toe drain" at a berm to the base of slope
Toe Drain (Catch Water Drain)	- Drain the water of the rain water which come down to the slope surface and the water from "Cascade Drain".
Subsurface Drainage	
Subsurface Drain	- Drainage of groundwater and seepage water from the slop surface
Gabion works	- Reinforcement of the base of a slope along with a subsurface drain
Horizontal Weep Hole, Horizontal Drainage Layer	- Drainage of spring water and seepage water from the slope surface - Drainage of water from an embankment or seepage water from the ground to an embankment

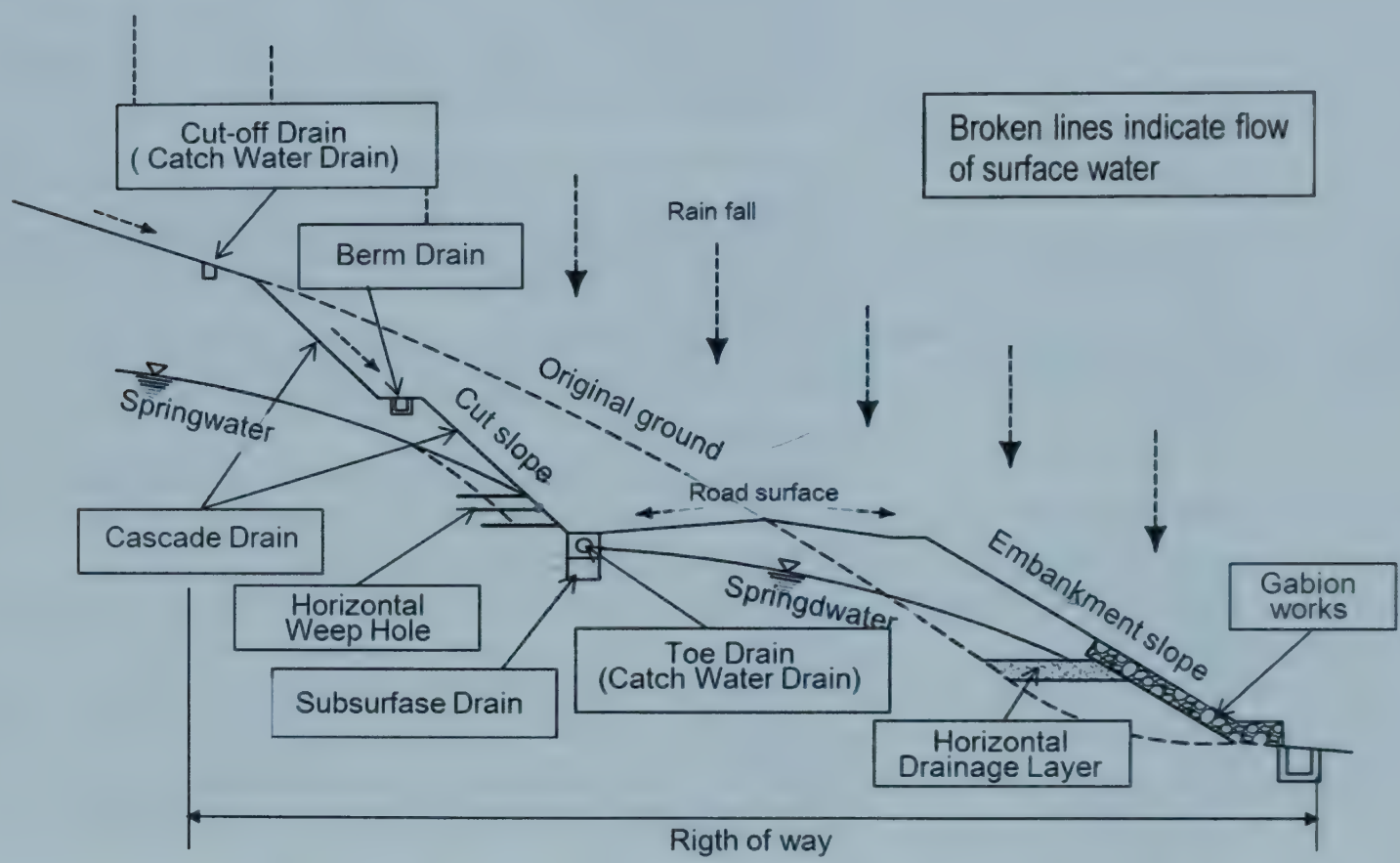


Figure 3-15 Examples of Slope Drainage Installation

In order to prevent erosion on the slope surface, it is necessary to reduce the amount of water flowing down the slope. Therefore, cut-off drains, berm drains, cascade drains and the like shall be installed as necessary in order to drain rainwater flowing down the slope. In addition, the spring water on the slope surface is caused by groundwater and rainwater that has infiltrated the ground and spring water on the embankment slope is caused by infiltrated water into the embankment from the road surface and the ground. Equipment for draining this spring water shall be installed, such as gabion, subsurface drain, horizontal drainage layer, horizontal weep hole and the like, as necessary, as shown in Figure 3-15.

a) Cut-off Drain and Toe Drain

The catch water drains installed on the slope are classified as either cut-off drains or

toe drains. These drains shall be installed so that surface water from the adjacent site does not enter the slope or road surface. For these designs refer to Clause 6.4 of IRC: SP: 73-2018 "Manual of Specifications and Standards for Two Laning of Highways with Paved Shoulder" and Clause 7.7 of HRB SR No.15 "Special Report, State of the Art, Landslide Correction Techniques".

b) Berm Drain

In the case of installing a berm on the slope, it is desirable to install a drain path called a berm drain in the berm. Berm drains are installed with concrete spray, concrete or a drainage ditch, for the purpose of guiding rain water on the slope surface to a cascade drain. In order to discharge water towards the drain, it is necessary for the berm to have a gradient of about 5% to 10%, as shown in Figure 3-16.

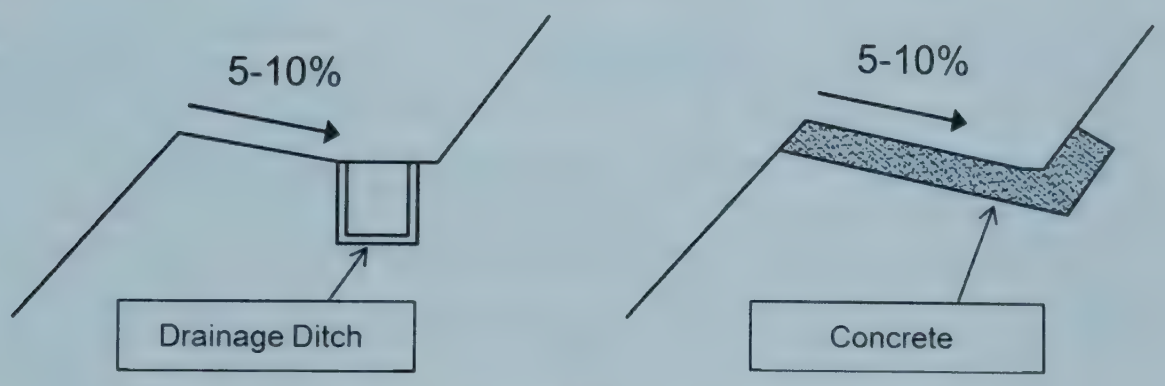


Figure 3-16 Type of Berm Drain and gradient

c) Cascade Drain

A cascade drain is a type of drain that is provided along the slope and is installed to guide water from a cut-off drain at the top of a slope and from a toe drain on a berm to the base of the slope. It is preferable for the structure of this drain to resemble the plain chutes or steeped chutes shown in Clause 4.4.9 of IRC: SP: 42-2014.

d) Subsurface Drainage

Subsurface drainage installed on the slope acts to modify the seepage pattern within the soil or rock mass and reduce the pore water pressure. The removal of water from within a slope by subsurface drainage is more expensive than surface drainage. However, subsurface drainage is usually more effective because it leads to a decrease in the pore water pressures directly at the failure plane. Hence, it is desirable to set drainage facilities as shown in Table 3-15 in accordance with ground conditions, such as the existence of spring water or groundwater on the slope.

Table 3-15 Subsurface Drainage Installed on Slope

Drainage Type	Function	Reference
Subsurface Drainage	Drainage of groundwater and seepage water from the slop surface	IRC: SP: 42-2014 IRC: SP: 73-2018 HRB SR No.15
Gabion works	Reinforcement of the base of a slope along with a subsurface drain	IRC: 56-2011 IRC: SP: 116-2018
Horizontal Weep Hole Horizontal Drainage Layer	Drainage of spring water and seepage water from the slope surface Drainage of water from an embankment or seepage water from the ground to an embankment	IRC: SP: 42-2014 HRB SR No.15

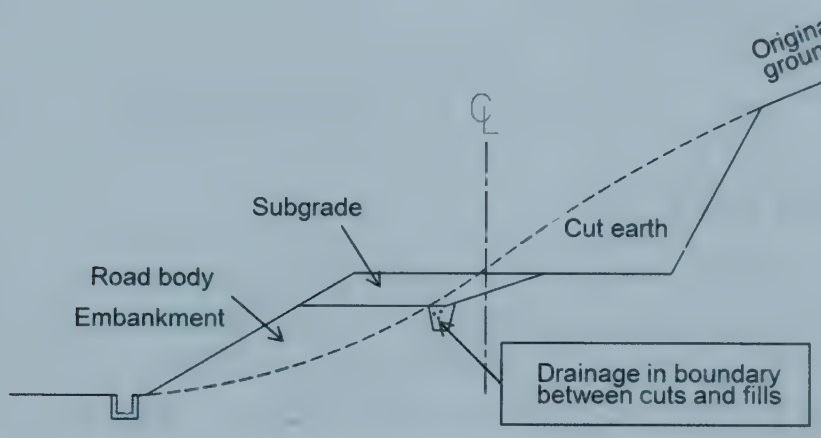
3.15.4 Subsurface Drainage System

3.15.4.1 Drainage within Road Body and Subgrade

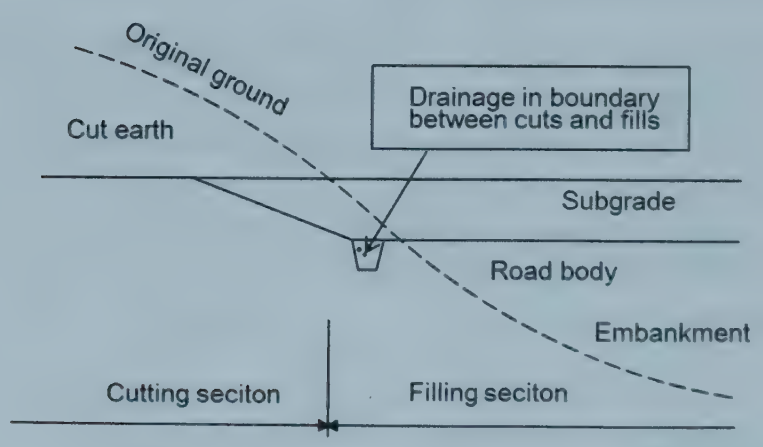
Drainage within road body and subgrade will reduce the groundwater level under the road surface for the purpose of maintaining the road body and subgrade well by blocking or draining the water penetrating from the adjacent land and road surface to road body and subgrade. If the water accumulates under the road surface, it will cause a decrease in the support force of the road body and the subgrade. Furthermore, the water may flow out from the seams of the pavement, roadside and cracks to the surface of the surface, which may cause damage to the pavement. For drainage within road body and subgrade, refer to IRC:SP:42-2014 "Guidelines on Road Drainage".

3.15.4.2 Drainage in Boundary between Cuts and Fills

When planning a hill road with the structure of boundary between cuts and fills, spring water infiltrates from the original ground into the road body and embankment, and it often causes instability of the embankment slope. In addition, water from rainfall easily gathers at the boundary between cutting and filling, so it is necessary to take appropriate measures into consideration. Therefore, it is desirable to install the subsurface drainage equipment in the boundary between cuts and fills as shown in Figure 3-17.



(a) Cross section view

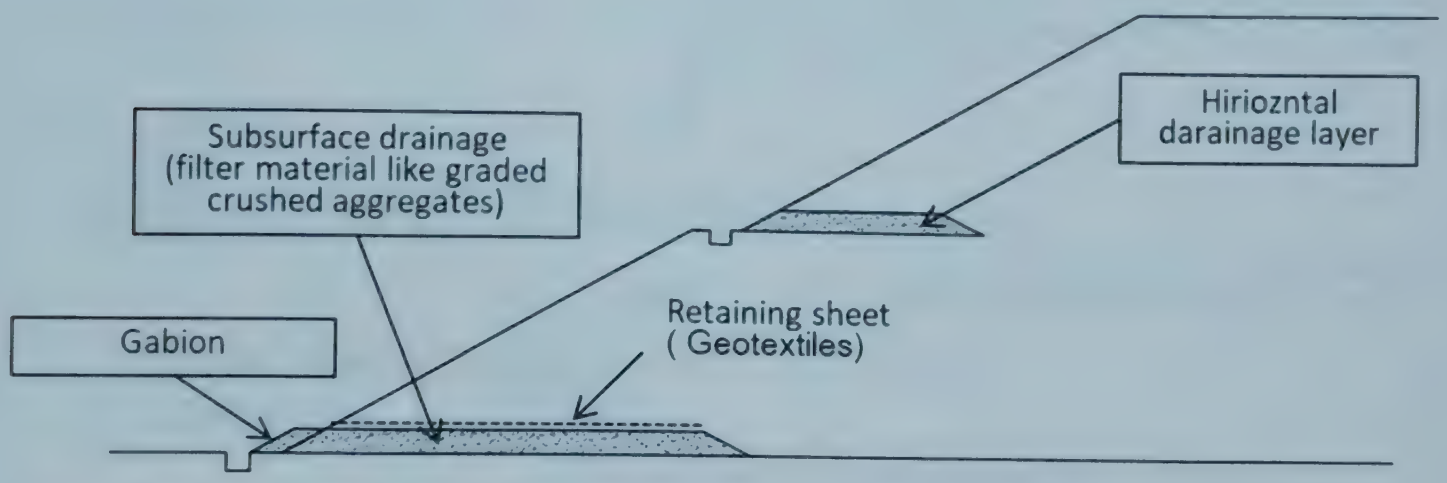


(b) Longitudinal section view

Figure 3-17 Example of Drainage Installation in Boundary between Cuts and Fills

3.15.4.3 Drainage within Embankment

Within high embankment, horizontal drainage layer and subsurface drainage that can discharge spring or seepage water out of the embankment should be installed to ensure stability of embankment. This horizontal drainage layer is similar to drainage layer that has been suggested by both MORTH Specifications and IRC:37 "Guidelines for the Design of Flexible Pavements".



(Source: Specifications for Highway Earthwork, Japan Road Association)

Figure 3-18 Example of Drainage Installation within Embankment

3.15.4.4 Drainage on Foundation Ground

Spring or seepage water from the ground where foundation of embankment is laid often raises groundwater level in the embankment that may destabilize the embankment slope and lead slope failures. In order to prevent the penetration of water from the ground to the embankment, drainage layer should be placed on the foundation ground. The drainage layer consists of filter material like graded crushed aggregates. Especially when embankment is installed in the following places, the drainage should be installed on foundation ground.

(1) High embankment

(2) Embankment in boundary between cuts and fills

(3) Embankment on stream

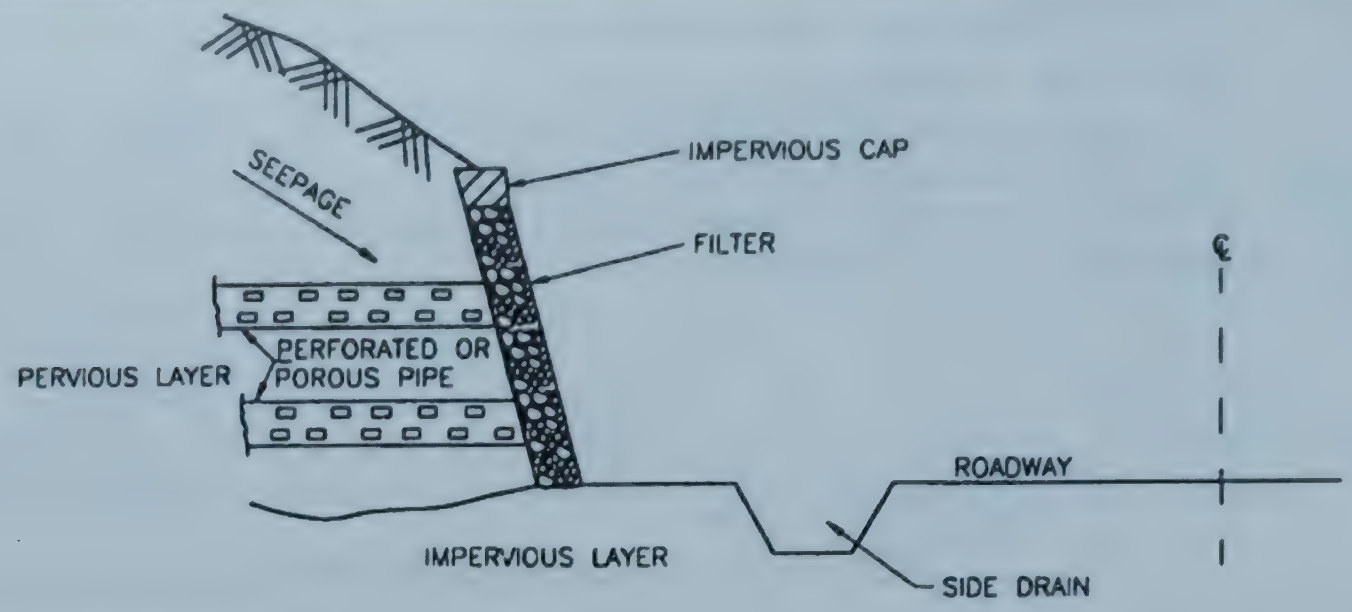
(4) Embankment filling the sloping ground

Especially, when embankment is to be installed on the stream with a lot of spring or seepage water from the ground, the perforated catchment pipe in the drainage layer is effective.

3.15.4.5 Drainage against Seepage from Hills

Seepage from hillsides in cut sections is a source from where embankment, subgrade, and sub-base get soaked. Roads are often damaged in stretches where there is excessive seepage from hills in absence of adequate sub-surface drainage.

Cut slopes which continually slough away at a point where seepage reaches the face can be stabilized by installing sub-soil drains at back of the cut face or toe-wall, such as Figure 3-19 according to IRC:SP:48-1998 "Hill Road Manual". In such cases, the drain is installed to a depth slightly below the previous material and backfilled with clean sand.

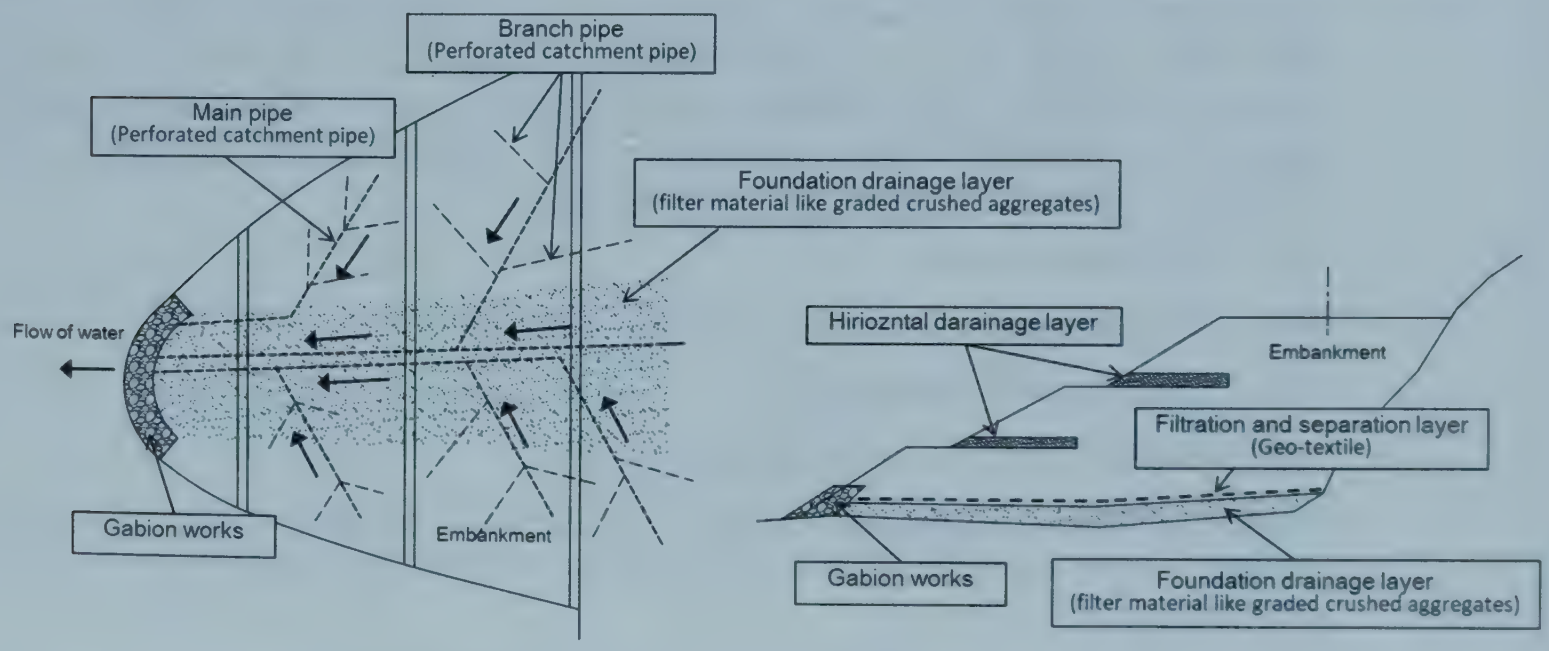


(Source: IRC:SP:48-1998 "Hill Road Manual")

Figure 3-19 Drainage against Seepage from Hills

3.15.4.6 Drainage at High Embankments

In the case of high embankment, breakage of the embankment often occurs due to permeation water and spring water together with surface water. In the case of embankments that fill the valleys in particular, it is desirable to have such a drainage system that permeable water, spring water and the like can be discharged outside the embankment by providing underground drainage grooves, horizontal drainage layers and foundation drainage layers, in order to ensure the stability of the embankment. Figure 3-20 shows an example of a drainage structure in an embankment filling a valley.



Plan view Cross-section view

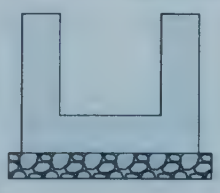
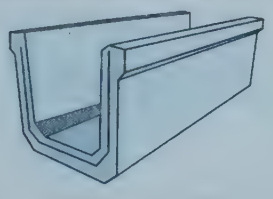
(Source: Specifications for Highway Earthwork, Japan Road Association)

Figure 3-20 Examples of Drainage Installation in Embankment Filling a Valley

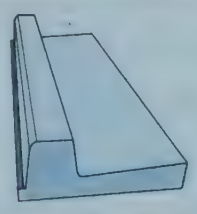
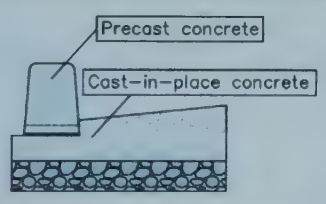
Reference: Concrete Roadside Drain in JAPAN (1/2)

Concrete roadside drains are the most common type of roadside drains and feature cross-sections that can be U-shaped, L-shaped, or circular, etc. In terms of their structure, they can be made of plain concrete or reinforced concrete, which can be precast, cast-in-place, or a combination of precast and cast-in-place concrete. Furthermore, there is a variety of combinations of cross-section shape that are possible (L-shaped and U-shaped or L-shaped and circular, for example). It is thus necessary to select the most suitable combination for the situation based on factors such as cost, workability, and ease of maintenance.

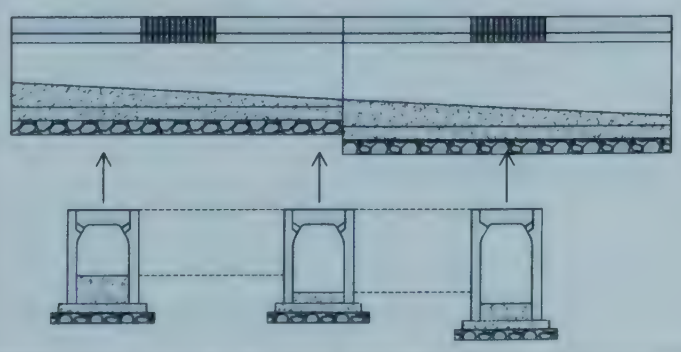
1. U-shaped side ditch

Cast-in-place concrete	Precast concrete	**Characteristics**
		- A typical concrete roadside drain used for draining large volumes of drainage water.

2. L-shaped side ditch

Precast concrete	Precast concrete + Cast-in-place concrete	**Characteristics**
		- A typical L-shaped roadside drain located between the sidewalk and traffic lane. - Capable of draining small volumes of water.

3. Free gradients side ditch

Precast concrete	**Characteristics**
	- By adjusting thickness of inverted concrete at the bottom, gradient of side ditch can be freely designed. **Benefits** - It facilitates the drainage in areas where the road gradient would obstruct wastewater flow.

(Source: Specifications for Highway Earthwork, Japan Road Association)

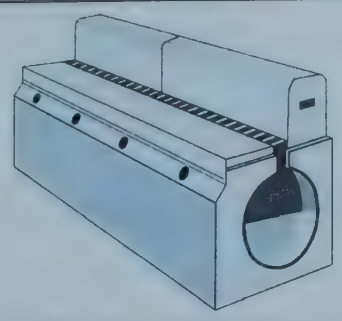
Reference: Concrete Roadside Drain in JAPAN (2/2)

4. Circular side ditch

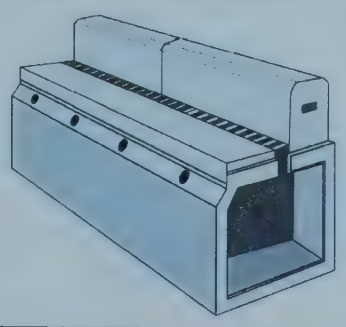
Characteristics
- Designed to have the functions of both L-shaped and U-shaped side ditches.
- Water from road surface is collected from a narrow opening at the top of the side ditch.

Benefits
- Because of the narrow opening, the width of the traffic lane can be used effectively.

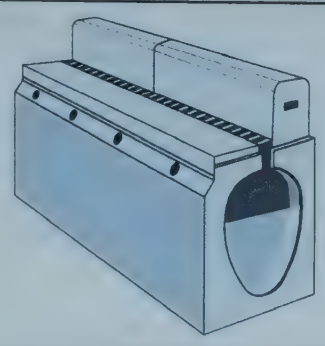
4-1. Circular side ditch

Precast concrete	**Characteristics** - Round shaped **Benefits** - Circular shaped bottom prevents deposits to the easily built up.
	

4-2. Rectangular side ditch

Precast concrete	**Characteristics** - Rectangular shaped **Benefits** - Enables the longest cross-section for drainage within the same cross-section.
	

4-3. Egg shaped side ditch

Precast concrete	**Characteristics** - Egg-shaped **Benefits** - It has higher flow capacity than circular or rectangular ones. - The bottom of the drain does not easily build up with deposits.
	

(Source: Specifications for Highway Earthwork, Japan Road Association)

APPENDIX REFERENCE TO ROAD PLANNING

Appendix 1 Classification of Roads

This appendix presents the types and definitions of roads in India and Japan for the reference to road planning.

A1-1. Road Classification in India and Japan

A1-1.1 Road Classification in India

Hill roads is roads passing through mountainous or steep terrain. Based on IRC:52-2019 "Guidelines for the Alignment Survey and Geometric Design of Hill Roads" and IRC:SP:48-1998 "Hill road manual", hill roads and other roads are classified as follows.

(1) General classification according to IRC:52-2019
   a) National highways
   b) State highways
   c) Major district roads
   d) Other district roads
   e) Village roads

(2) Practical classification according to IRC:48-1998
   a) Major road for fast vehicle
   b) Bridle road for pedestrian, horse
   c) Village track

A1-1.2 Road Classification in Japan

In Japan, roads are classified into following six types. The management organizations are national government, district governments, municipalities and expressway companies.

(1) General classification according to type and grade of roads
   a) Expressways
   b) National highways
   c) District highways
   d) Major district roads
   e) Other district roads
   f) Municipal roads

A1-2. Design Speed of Roads in India and Japan

A1-2.1 Design Speed of Roads in India

On the basis of the design speed defined in IRC:SP:48-1998 "Hill Road Manual" and IRC:SP:73-2018 "Manual of Specifications and Standards for Two Laning of Highways with Paved Shoulder", the design speeds for various categories of roads in India are given in Table A-1 and Table A-2.

Table A-1 Design Speed in India

Road Classification	Mountainous Terrain (km/h)		Steep Terrain (km/h)	
	Ruling	Min	Ruling	Min
National and State Highways	50	40	40	30
Major District Roads	40	30	30	20
Other District Roads	30	25	25	20
Village Roads	25	20	25	20

(Source: IRC:SP:48-1998 "Hill Road Manual")

Table A-2 Design Speed in India (Tow-lane and four-lane highways)

Nature of Terrain	Cross Slope of the Ground	Mountainous Terrain (km/h)	
		Ruling	Min
Plain and Rolling	Up to 25 percent	100	80
Mountainous and Steep	More than 25 percent	60	40

(Source: IRC:SP:73-2018 "Manual of Specifications and Standards for Two Laning of Highways with Paved Shoulder")

(Source: IRC:SP:84-2019, "Manual of Specifications and Standards for Four Laning of Highways")

A1-2.2 Design Speed of Roads in Japan

On the basis of Road Structure Ordinance, the design speeds for various categories of roads in Japan are given in Table A-3.

Table A-3 Design Speed in Japan

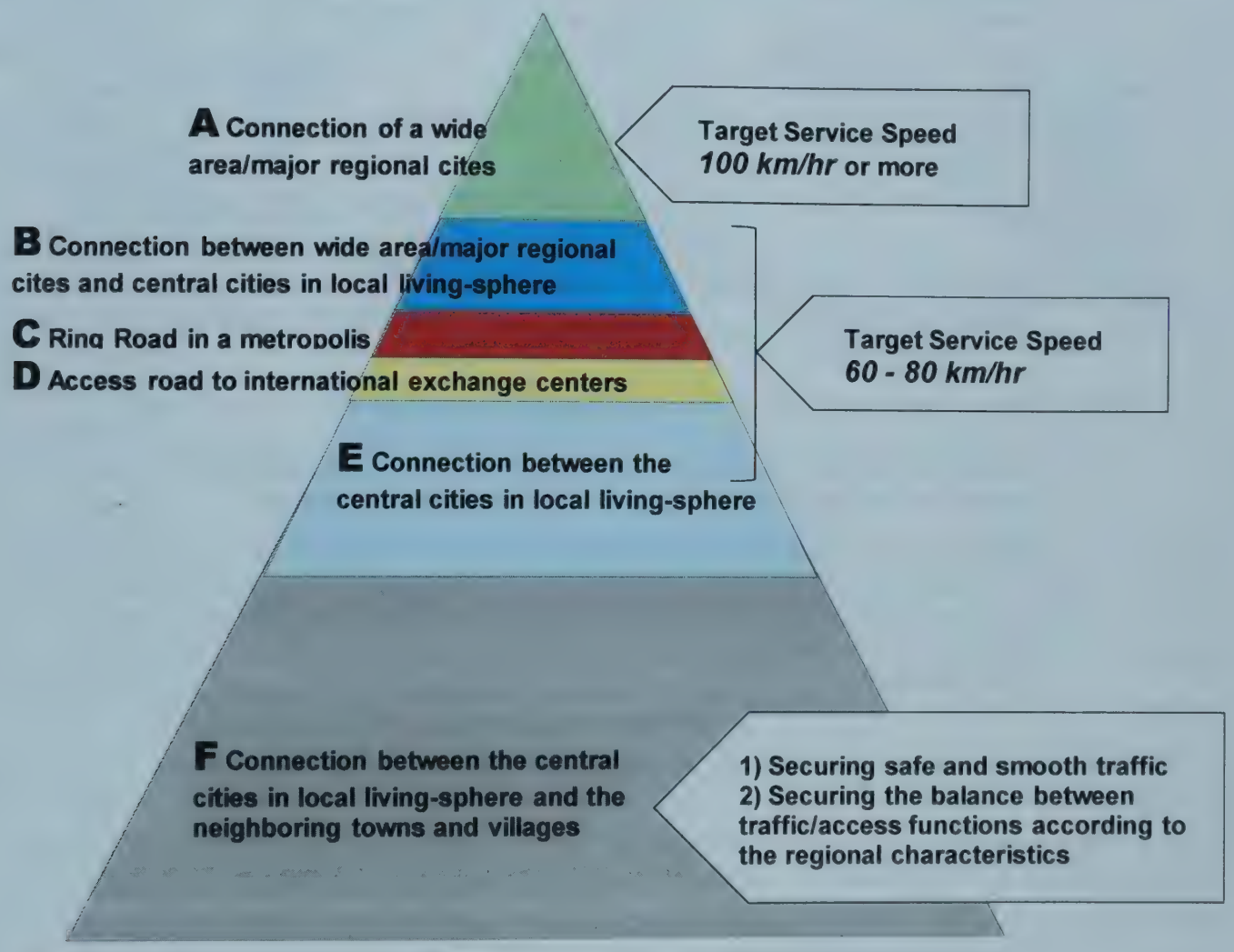
Road classification	Lane Number	Design Speed (km/h)	
		Mountainous Terrain	
		Ruling	Min
Expressways	Above four-lane	60, 80, 100	50, 60, 80
National Highways	Above four-lane	60	40, 50
	Two-lane	40, 50, 60	30
Major District Roads Other District Roads	Two-lane	40, 50, 60	30
District Roads Municipal Roads	1.5-lane to 2-lane	30, 40, 50	20
	One-lane	30, 40, 50	N/A

(Source: Commentary and application of road structure ordinance, Japan Road Association)

A1-3 Hierarchy and Required Function of Roads in Japan

The hierarchy and required function of roads in Japan are shown in Figure A-1 and Table A-4, respectively. In Japan, the roads and the road networks are classified into six categories, and developed on the basis of each required function.

The concept of a hierarchical road network was firstly introduced in Buchanan Report (1963), and is now widely recognized as a basic idea of the road planning. In order to realize the theory, in the United States (AASHTO, 2011) and Japan (MLIT, 1992), performance target values such as travel speed and level of service are calculated for each road hierarchy.


A Connection of a wide area/major regional cites
Target Service Speed
100 km/hr or more
B Connection between wide area/major regional cites and central cities in local living-sphere
C Ring Road in a metropolis
D Access road to international exchange centers
Target Service Speed
60 - 80 km/hr
E Connection between the central cities in local living-sphere
F Connection between the central cities in local living-sphere and the neighboring towns and villages
1) Securing safe and smooth traffic
2) Securing the balance between traffic/access functions according to the regional characteristics

(Source: Wide Area Highway Development Plan, MLIT)

Figure A-1 Hierarchy and Roads

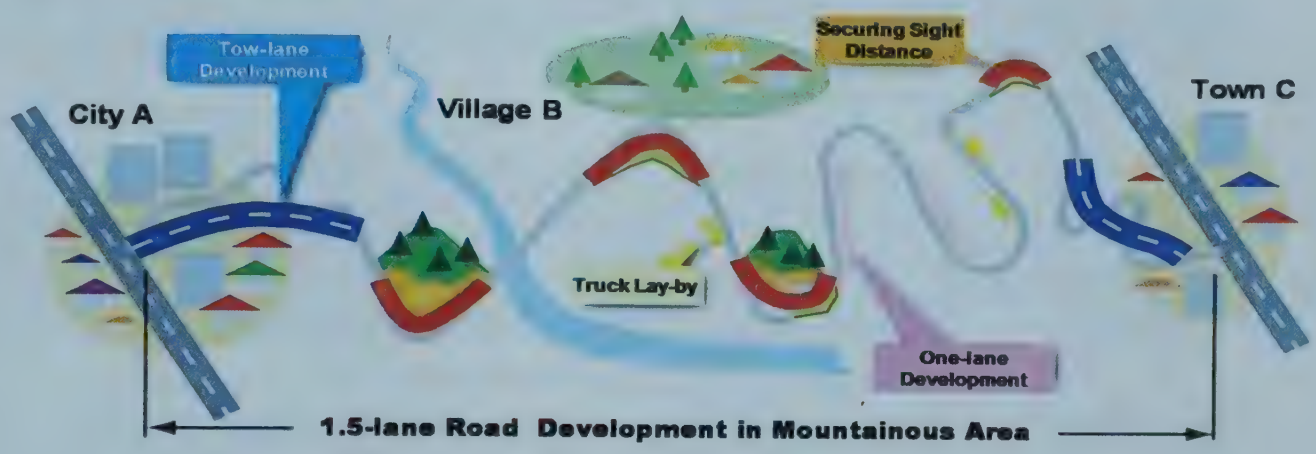
Table A-4 Required Function of Roads

Components of Road Network		Target of Road Network	Required Function of Road Network
A	Connection of a wide area/major regional cites	Optimization of wide area logistics Integration of the national land through wide-area cooperation and exchange Mutual complement of resources and functions among regional blocks	High speed and high punctuality traffic function Secure reliability against disasters
B	Connection between wide area/major regional cites and central cities in local living-sphere	Sharing the services of the city widely within the regional block Create of unity of the region through collaboration and exchange within the regional block	Expansion of day trip area from major city Secure smooth access to major city Secure reliability against disasters
C	Ring Road in a metropolis	Traffic facilitation in urban areas and reduce CO_2 emissions Improvement and reformation of urban system structure	Secure traffic capacity for smooth urban transport
D	Access road to international exchange centres (areas)	Expansion and optimization of economic exchange between international exchange area and regional block	Direct connection to airports and harbours as a major area Secure operation of international marine container vehicles
E	Connection between the central cities in local living-sphere	Complementarity and cooperation of function of cities in local living-sphere	Secure smooth traffic Secure reliability against disasters
F	Connection between the central cities in local living-sphere and the neighbouring towns and villages	Secure basic services (medical, shopping, public services) in a population declining area Formation of landscape and provision of attractive public space	Secure safe and smooth daily traffic Secure space functions according to local needs

(Source: Wide Area Highway Development Plan, MLIT)

Reference: Road System with Flexible Lane Number in Japan

In order to satisfy the traffic demand in mountainous areas, local roads, which have been originally planned to be two lanes, can be improved by flexibly combining one lane development and two lanes development based on the local conditions. In this road system, some parts of the roads are developed to be one lane, while other parts are constructed to be two lanes depending on the traffic demands. The introduction of this road system contributes to secure the minimum traffic function and early road construction for local roads with low traffic demands in mountainous areas. This road system with flexible lane number is widely known as "1.5-lane road development" in Japan. A brief conceptional image of "1.5-lane road development" is shown as follows.



Brief Concept of 1.5-lane Road Development in Mountainous Area

The development of the road system with flexible lane number is one of the methods to ensure the minimum traffic function from the topography of the local area and the usage of the existing road. The road system with flexible lane number contributes to secure the minimum road function and continuous development by utilizing existing roads. Additionally, this road system enables to prepare truly necessary roads according to the local conditions in the mountainous areas.

In general, for the development of two-lane roads in the mountainous areas, large-scale topographical modification is required regardless of low traffic volume, and thus the project results in significant increases of project costs and large influences on the natural environment around the project areas. In the road system with flexible lane number, efficient and effective road development can be done at an early stage within a limited budget. In the development of this road system, consensus formation with local residents is a major premise, and it is important to adopt the road structures suitable for the region while considering various needs of local residents.

It should be noted that it is necessary to carry out sufficient field survey and route selection when using the existing roads.

(Source: Commentary and application of road structure ordinance, Japan Road Association)

Appendix 2 Design Service Volume of Roads

This appendix presents the design service volume of hill roads in India, Japan and US for the reference to road planning. In India, different values of the design service volume are adopted in some existing manuals. The values of the design service volume in India and Japan are shown in A2-1 and A2-2, respectively.

A2-1. Design Service Volume in India

On the basis of the design service volume defined in IRC:SP:48-1998 "Hill Road Manual", IRC:SP:73-2018 "Manual of Specifications and Standards for Two Laning of Highways with Paved Shoulder" and IRC:SP:84-2019 "Manual of Specifications and Standards for Four Laning of Highways", the design service volume of roads in India are given in Table A-5, Table A-6, and Table A-7.

Table A-5 Recommended Design Service Volumes for Hill Roads in India

Type of Road	Carriageway Width (m)	Design Service Volume (PCU/day)	
		For Low Curvature (0-200 degrees per km)	For High Curvature (above 200 degrees per km)
Single Lane	3.75	1,600	1,400
Intermediate Lane	5.5	5,200	4,500
Two Lanes	7	7,000	5,000

(Source: IRC:SP:48-1998 "Hill Road Manual")

Additionally, the design service volume of two-lane highway of different type of terrain shall be as per the latest guidelines of the MoRTH which is at present specified in circular no. RW/NH-33044/37/2015/S&R(R) dated 26th May, 2016 as given in Table A-6.

Table A-6 Recommended Design Service Volumes for Hill Roads in India (Two-lane highways)

Nature of Terrain	Design Service Volume (PCU/day)
Plain	10,000
Rolling	8,500
Mountainous and Steep	6,000

(Source: IRC:SP:73-2018, "Manual of Specifications and Standards for Two Laning of Highways with Paved Shoulder")

Moreover, the design service volume of different terrain conditions and level of service shall be as specified in Table A-7.

Table A-7 Recommended Design Service Volumes for Hill Roads in India (Four-lane highways)

Nature of Terrain	Design Service Volume (PCU/day)	
	Level of Service 'B'	Level of Service 'C'
Plain and Rolling	40,000	60,000
Mountainous and Steep	20,000	30,000

(Note: The definition of PCU is as per IRC:64-1990, "Guideline for Capacity of Roads in Rural Areas")

(Source: IRC:SP:84-2019, "Manual of Specifications and Standards for Four Laning of Highways")

A2-2. Design Service Volume in Japan

On the basis of Road Structure Ordinance, the design service volume of roads in Japan are given in Table A-8 and Table A-9. For roads in rural areas, the design service volume is set to be less than the values shown in Table A-8 and Table A-9 based on the topographical conditions. It should be noted that the readers are recommended to convert the units of vehicle/day or vehicle/day/lane to that of PCU/day when the readers compare the design service volumes between India and Japan.

Table A-8 Recommended Design Service Volumes in Japan (Two-lane roads)

Nature of Terrain	Design Service Volume (vehicle/day)	
	Expressway	Other roads
Plain	13,000 - 14,000	8,000 – 9,000
Mountainous and Steep	9,000 - 10,000	6,000

(Source: Commentary and application of road structure ordinance, Japan Road Association)

Table A-9 Recommended Design Service Volumes in Japan (More than Four-lane roads)

Nature of Terrain	Design Service Volume per lane (vehicle/day/lane)	
	Expressway	Other roads
Plain	11,000 - 12,000	8,000 – 11,000
Mountainous and Steep	8,000 - 9,000	5,000 – 7,000

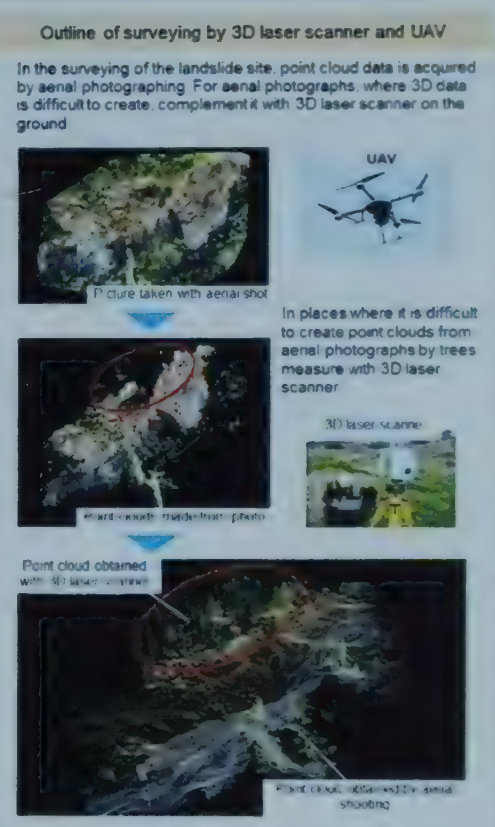
(Source: Commentary and application of road structure ordinance, Japan Road Association)

Appendix 3 Advanced Techniques for Road Planning

This appendix introduces four advanced technologies that are beneficial to adapt at the planning stage. The novelties and expected effects of these techniques are outlined. In addition, the adaptability to the India's hill roads and points to be noted when applying these techniques to road projects are also described.

1. Topographic survey (3D Surveying, UAV, Laser Scanner)

Name of Advanced Technology	**Space Measurement System with UAV (Drone) and 3D Laser Scanner**
	System that creates 3D drawings such as current survey and shape measurement using photograph data acquired by UAV and point group data acquired by 3D laser scanner
Summary	Contents of advanced technology
	■ 3D space measurement system using UAV and 3D laser scanner
	Conventional technical correspondence
	■ Topographic surveying using a total station
	Application to public works
	■ Topographic surveying ■ Route surveying
	Others
	■ UAV is an abbreviation for Unmanned Aerial Vehicle and is a generic term for aircraft that fly unmanned. ■ The selection of measuring equipment shall be made in consideration of the situations of the site. ■ UAV alone measurement is also possible. Measurement with only a 3D laser scanner is NETIS registered. (Registration number: HR-060028-VE) ■ The following results are obtained with this technology. • Manufacturing management • Bird's-eye view creation • Fixed Point Observation (In particular, it is possible to precisely reproduce structures buried in the future, which can be used for maintenance and disaster prevention) • 3D terrain data in i-Construction and CIM • Improve safety on measurement of altitude / dangerous parts • Improvement in the accuracy of quantity calculation for places where expression is difficult in two dimensions • Improve representation of surveying and measurement data • Construction plan and simulation using 3D data


Outline of surveying by 3D laser scanner and UAV
In the surveying of the landslide site, point cloud data is acquired by aerial photographing. For aerial photographs, where 3D data is difficult to create, complement it with 3D laser scanner on the ground
UAV
Picture taken with aerial shot
In places where it is difficult to create point clouds from aerial photographs by trees measure with 3D laser scanner
3D laser scanner
Point cloud obtained

<table>
<tr><td rowspan="6">Novelty and Expected Effects</td><td>Novelty and improvement (Compared to conventional technology)</td></tr>
<tr><td>■ Topographic survey conducted by TS was changed to survey using UAV and 3D laser scanner</td></tr>
<tr><td>Expected effect (Advantage of utilization of advanced technology)</td></tr>
<tr><td>■ 3D points cloud data such as the topography of the entire site can be acquired in a short time, thus saving labour and shortening the construction period
■ Safety has been improved because it can be measured without entering the site
■ As labour costs can be reduced due to reduction of on-site surveying work, economic efficiency has been improved
 </td></tr>
<tr><td>Others</td></tr>
<tr><td>■ 3D points cloud data of acquired terrain can be used as basic data in i-Construction and CIM</td></tr>
<tr><td rowspan="8">Condition of Application</td><td>Natural conditions</td></tr>
<tr><td>• Not being under night conditions, rainfall, snowfall, fog conditions
• It shall not be under the condition of wind speed of 8 m/sec or more
• Air temperature range from 0 °C to 40 °C</td></tr>
<tr><td>Site conditions</td></tr>
<tr><td>■ Do not fly without permission under the following range and conditions
• Airspace with a height of 150 m or more above the ground or water surface
• Airspace above the entrance surface etc. set around the airport etc.
• Over the population concentration area (excluding the area specified by the MLIT) set according to the result of the census
• A range in which the aircraft cannot be monitored visually. Approximate range is based on "Safety standard concerning the use of UAV in public survey (draft)"
• The distance to a person or property is less than 30 meters
• Festivities, skies over which many people gather
However, when flying under these ranges and conditions, apply to the MLIT or the jurisdiction airline office and fly safely with permission (see: Chapter 9 Unmanned Aerial Vehicle Law of the MLIT Article 132)</td></tr>
<tr><td>Technically available area</td></tr>
<tr><td>• Unlimited</td></tr>
<tr><td>Applicable laws and regulations</td></tr>
<tr><td>• Surveying law
• Aviation law
• Wireless radio act
• Civil law
• Road traffic law</td></tr>
<tr><td rowspan="4">Scope of Application</td><td>Applicable range</td></tr>
<tr><td>• Topographic surveying and route surveying outdoors</td></tr>
<tr><td>Particularly effective application range</td></tr>
<tr><td>• Terrain and route surveying of collapsed areas and disaster sites (restricted areas and hazardous areas)
• Measurement of places requiring platforms or aerial work vehicles
• Large scale construction work
• 3D measurement for i-Construction and CIM</td></tr>
</table>

	Unacceptable range
	• Location where flight permission or approval cannot be obtained under the revised Aviation law and flight methods • Location where GPS reception status is not good
	Relevant criteria and source
	• Rules of Public Surveying Work Regulations (March 29, 2013) • Public survey manual using UAV (draft) (March 30, 2016) • Safety standards on the use of UAV in public survey (draft) (March 30, 2016)
Notice	**Route selection/road design stage**
	The aircraft uses a UAV that has a "Technical standards compliance-mark" that conforms to the Wireless radio act. When flying in the following airspace, permission from the MLIT is required • Airspace with a height of 150 m or more above the ground or water surface • Airspace above the entrance surface etc. set around the airport etc. • Over the population concentration area (excluding the area specified by the Minister of Land, Infrastructure, Transport and Tourism by the MLIT) set according to the result of the census In the case of flying under these ranges and conditions, apply to the MLIT or the jurisdiction aviation office and fly safely with permission (see: Municipal and Traffic Aircraft Chapter 9 Unmanned Aerial Vehicle No. 132 Article) In addition, in the following cases, obtain certain permission • When flying over the private land (permission for land ownership) • When flying on a road (permission based on the Road traffic law)
	Construction stage
	• To fly during the day • Always monitor unmanned aerial vehicles and their surroundings within the visual range and let them fly. The surveillance system conforms to "Safety standard concerning the use of UAV in public survey (draft)". • To fly with a distance of 30 m or more between people, buildings, automobiles and other objects • Do not let it fly above festivals where many people gather, such as festivals and festivals • Do not transport hazardous materials such as explosives, high pressure gas, inflammable liquids, weapons, etc. • Do not throw objects from unmanned aerial vehicles • Observation of the reference point and the measurement reference points and the orientation points of the 3D measurement shall be performed by reference point surveying using the TS
	O&M stage
	• None
	Others
	• None
Adaptability to hill roads in India	It is suitable for topographic surveying and route surveying of hill roads in India where manpower work with total station will be difficult because of steep terrain.
Expectation of Application to model project	While introducing advanced technology, it is necessary to consider the following: (1)Condition of the candidate area (topography, features, environment, etc.), (2)Possibility of technical application, (3)Intention of the developer and the receiving side, (4)Effects of implementation and (5)Develop ability (future prospect).

Effectiveness of introducing advanced technology

Effectiveness: *reported by Developer

Effectiveness of introduction				
Comparative prior technology		Survey by TS (Total-Station)		
Item	Effect of introduction			Evaluation concept
Economic efficiency	✓Improvement (38%*)	Same level	Decrease	Field survey work can be greatly reduced, and labour costs are reduced.
Schedule	✓Shortening (50%*)	Same level	Increase	It is possible to drastically reduce field survey work.
Quality	✓Improvement	Same level	Decrease	Expression power will be improved because plotting is performed using many three (3) - dimensional data for the entire current condition.
Safety	✓Improvement	Same level	Decrease	Measurement becomes possible without entering the site.
Workability	✓Improvement	Same level	Decrease	It is possible to measure a wide area with a small number of labours in a short time.
Impact on the surrounding environment	Improvement	✓Same level	Decrease	There is no difference in impact.
Deployment of toward IT	✓Improvement	Same level	Decrease	It can be used as basic data in CIM (Construction Information Modelling and Management).
Selling points of technology	Conventionally, since the survey was carried out at the TS, it was necessary to enter the hazardous location, which required a lot of manpower and time. By introducing this technology, it will be expected to save labour for data acquisition, shorten the construction period, and improve safety.			

(Source: NETIS (New Technology Information System), MLIT, Japan/ February, 2018)

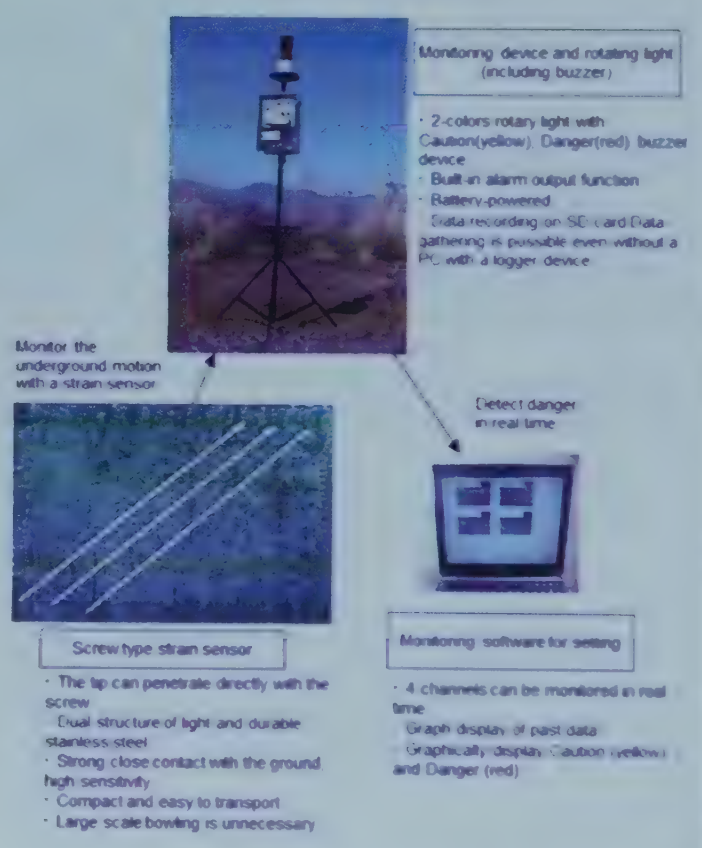
2. Slope condition survery (Slope Displacement Detection, Fixed Type, Strain Sensor)

Name of advanced technology	**Slope Strain Monitoring System**
	Existing natural slope, cutting slope and ground disaster monitoring support system of excavation work
Summary	Contents of advanced technology
	■ In this system, a screw type strain sensor penetrating into the ground detects a strain of a shallow soil layer caused by instability of the slope. It monitors the risk of slope failures and issues a warning to workers when fluctuations occur in moving clods.
	Conventional technical correspondence
	■ Ground Telescopic Meter: When used for safety control of slope of the decoration surface and excavation work, it consists of a ground extensometer (with alarm output function) + alarm machine (relay box) + rotating lamp and buzzer.
	Application to public works
	■ Existing natural slope where there is a risk of collapse, cutting surface, site where simple safety monitoring is carried out in excavation work.
	Others
	■ This system consists of a "screw type strain sensor" for detecting strain, a "monitoring device" for data acquisition, analysis processing, alarm output, and a rotating lamp for emitting an alarm, penetrating a strain sensor in an unstable lump, monitoring Install and wire the equipment, use the rotary light wired to the monitoring equipment. ■ The screw type strain sensor detects the shear deformation generated in the shallow soil layer (1m) due to instability of the slope by bending (compression, tensile strain) of the sensor. ■ Monitor and measure the slope "moving", "stopped", "whether movement is fast". If it exceeds the pre-set value, inform the worker with an alarm. ■ Alarm indication: No light: Normally, yellow lit: attention, red lit: evacuated in three stages. ■ The warning level setting value has three levels (weak, moderate, strong) level setting and arbitrary setting by the personal computer with strain change amount (rapid increase, accumulation) and strain change increment (inclination) per time.

Sample of system configuration (Safety control measures)

Name of Equipment	Quantity	Component	Functions
Screw type strain sensor	1~4 pieces	Sensor, connection cable, pressure receiving plate	Equip with the screw at the tip of the sensor. Determine the number of installations according to the site
Monitoring device	1 unit	Memory card, LAN cable, 1 battery	Measure the sensor 4 ch simultaneously. Alarm output function available. The setting value can be arbitrarily set to 3 levels (slight, medium, serious). Rotary lights can be broadcasted on 4 ch all at once and individually
Exclusive turning light	1 unit	Dedicated red/yellow light 2 colors	Caution(yellow), Danger(red) and Buzzer(85db)
Exclusive tripod	1 unit	-	Rotary light can be installed at the top
Strain monitor software	1 set	-	Simple graph display, alarm setting
Exclusive excavator	1 unit	-	for Pre-Boring

Outline of slope strain monitoring system


Monitoring device and rotating light (including buzzer)
・2-colors rotary light with Caution(yellow), Danger(red) buzzer device
・Built-in alarm output function
・Battery-powered
Data recording on SD card Data gathering is possible even without a PC with a logger device
Monitor the underground motion with a strain sensor
Detect danger in real time
Screw type strain sensor
・The tip can penetrate directly with the screw
Dual structure of light and durable stainless steel
・Strong close contact with the ground high sensitivity
・Compact and easy to transport
・Large scale bowling is unnecessary
Monitoring software for setting
・4 channels can be monitored in real time
Graph display of past data
Graphically display Caution (yellow) and Danger (red)

■ The amount of strain change is measured in units of micro strain (μs), so it is not possible to ascertain the amount of movement (mm) as in a ground extensometer.

<table>
<tr><td></td><td>
■ Strain sensor dimensions (length 1,065mm, width 31mm <screw part>), mass: approximately 600g.
■ The strain sensor can penetrate with a hexagonal 19 mm cross wrench.
■ The power supply is battery operated.
</td></tr>
<tr><td rowspan="6">Novelty and expected effects</td><td>Novelty and improvement (Compared to conventional technology)</td></tr>
<tr><td>■ Conventionally, stake at the fixed point and the moving point, stretched the invar line, and measured the amount of expansion and contraction of invar wire between stationary and moving points. The screw type strain sensor was set to penetrate into a place (movement point) where there is a danger of collapse and the amount of strain applied to the sensor was measured.</td></tr>
<tr><td>Expected effect (Advantage of utilization of advanced technology)</td></tr>
<tr><td>■ By installing a screw type strain sensor in a place where there is a danger of collapse (moving point) and measuring the amount of strain applied to the sensor, it is possible to save labour for the installation and adjustment work of the inverse wire which was conventionally necessary, Improvement of economy, reduction of construction period, improvement of workability can be expected.</td></tr>
<tr><td>Others</td></tr>
<tr><td>
■ Sensors can be installed at four locations (four) by one monitoring device, measurement monitoring is possible, and economic efficiency is increased in the site where multiple units are installed.
■ The monitoring equipment is equipped with a data recording function, an alarm output function, and a rotating lamp connection unit, which helps in cost reduction increases the cost reduction effect as one unit.

Example of test installation site sensor installation site
■ Adopt a light and durable stainless-steel double tube structure screw type strain sensor.
■ Measurement data is recorded on a memory card and can be confirmed and analysed separately on a personal computer using the dedicated software "Strain Monitor".
■ Always monitor by connecting with PC via LAN cable
■ Measure the strain value every 10 seconds.
■ The alarm setting of the monitoring device can be determined by increment (inclination) of the strain change amount per unit time in addition to the strain change amount (rapid increase, cumulative change).
■ By checking the increment (inclination) of the strain change amount, it is possible to check whether the movement of the slope is fast.
</td></tr>
<tr><td rowspan="8">Condition of application</td><td>Natural conditions</td></tr>
<tr><td>• The monitoring device can operate in the range of -10 °C to 50 °C</td></tr>
<tr><td>Site conditions</td></tr>
<tr><td>• The distance of the connecting cable from each sensor to the monitoring device installation location (occupied area 1 m^2) can correspond to 100m.</td></tr>
<tr><td>Technically available area</td></tr>
<tr><td>• Unlimited</td></tr>
<tr><td>Applicable laws and regulations</td></tr>
<tr><td>• None</td></tr>
</table>

Scope of application	Applicable range
	• Locations of the ground where the screw type strain sensor can penetrate. (N value is 15 or so due to intrusion by human force) • Locations where people can approach to install and remove screw type strain sensors.
	Particularly effective application range
	• Used in places where need to be installed and removed in a short time.
	Unacceptable range
	• Locations where there are many rocky and rolling stones. (Screw type strain sensor cannot penetrate) • Cutting slopes collapse due to excavation if the sliding surface is deeper by more than 1 m and the horizontal movement occurs, screw strain sensors cannot detect bending strain and cannot be picked up.
	Relevant criteria and source
	• None
Notice	Route selection/road design stage
	• Geological engineers should examine the installation location. • Check that the screw type strain sensor can be buried in the ground.
	Construction stage
	• If the condition of the ground is not known, perform pre-boring with a special auger or the like before installing it so as not to damage the screw type strain sensor when penetrating. • Ensure that the screw type strain sensor penetrates the ground. • Point the sensor red reference line in the direction of movement (mountain to valley direction). • When a gap is formed between the sensor and the earth, the sensitivity of the sensor is dull, so fill it with soil and so on. • Fix the monitoring device securely. • The monitoring equipment should be installed in places where visibility is not directly hit by direct sunlight. • The location where monitoring equipment is installed shall be within 100 m from each sensor. • Route the cables between each sensor and the monitoring device so as not to disturb the construction. Also, the cable should be properly protected according to circumstances so as to prevent bite injury such as cutting and small animals during construction.
	O&M stage
	• Battery power supply has a function to notify voltage drop. When the voltage drop is confirmed, replacement of the battery is necessary. (It usually needs replacement in about 80 hours and 20% in winter) • The monitoring device has a sensor abnormality warning function. When turning on the lamp, it is conceivable that the cable is disconnected, so it is necessary to check it. • The screw type strain sensor can be used repeatedly depending on the usage situation, but in the case of deformation or sensor abnormality, replacement is necessary.
	Others
	• The alarm set value (inclination, rapid increase judgment) is currently set based on actual size test data. (It can be set by monitoring software) Reference: Special Report on Labour Safety and Hygiene Research Institute, Independent Administrative Institution No. 35-2007 Experimental Study on Development of Screw Surface Strain-meter for Simple Safety Monitoring on Slope Construction and its Application

<table>
<tr><td>Adaptability to hill roads in India</td><td>It is possible to detect the strain of the shallow part of the existing slope where landslides occur frequently, monitor the danger of the slope collapse at an early stage, and issue an alarm to the workers.</td></tr>
<tr><td>Expectation of application to model project</td><td>In introducing advanced technology, it is necessary to consider the following: (1)Condition of the candidate area (topography, features, environment, etc.), (2)Possibility of technical application, (3)Intention of the developer and the receiving side, (4)Effects of implementation and (5)Develop ability (future prospect).</td></tr>
<tr><td>Effectiveness of introducing advanced technology</td><td>Effectiveness: *reported by Developer
<table>
<tr><th colspan="5">Effectiveness of introduction</th></tr>
<tr><td colspan="2">Comparative prior technology</td><td colspan="3">Ground strain meter</td></tr>
<tr><td>Item</td><td colspan="3">Effect of introduction</td><td>Evaluation concept</td></tr>
<tr><td>Economic efficiency</td><td>✓Improvement (29%*)</td><td>Same level</td><td>Decrease</td><td>Installation labour cost related to the installation and adjustment of Invar wire which was conventionally necessary can be reduced.</td></tr>
<tr><td>Schedule</td><td>✓Shortening (78%*)</td><td>Same level</td><td>Increase</td><td>ditto</td></tr>
<tr><td>Quality</td><td>Improvement</td><td>✓Same level</td><td>Decrease</td><td>There is no difference in impact.</td></tr>
<tr><td>Safety</td><td>Improvement</td><td>✓Same level</td><td>Decrease</td><td>There is no difference in impact.</td></tr>
<tr><td>Workability</td><td>✓Improvement</td><td>Same level</td><td>Decrease</td><td>Installation labour cost related to the installation and adjustment of Invar wire which was conventionally necessary can be reduced.</td></tr>
<tr><td>Impact on the surrounding environment</td><td>Improvement</td><td>✓Same level</td><td>Decrease</td><td>There is no difference in impact.</td></tr>
<tr><td>Selling points of technology</td><td colspan="4">By adopting the screw type strain sensor, it can penetrate directly into the ground, it is possible to shorten the installation process of installing the invar wire, adjustment, protection pipe and labour saving, improve the workability and reduce the cost.</td></tr>
</table></td></tr>
</table>

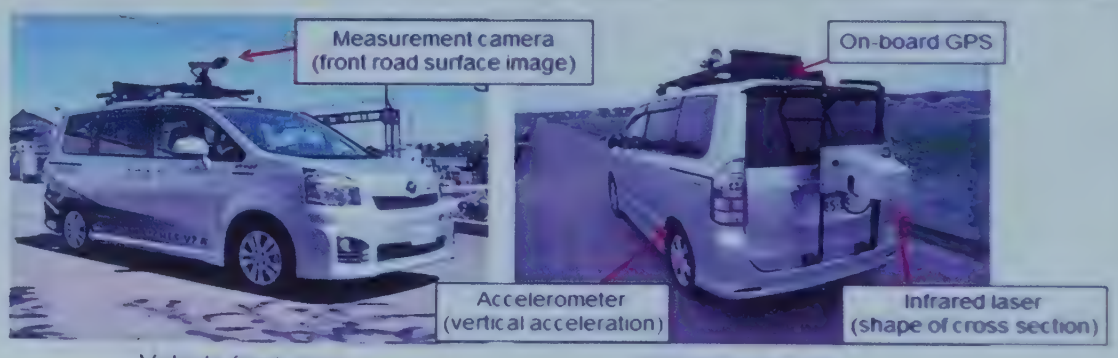
(Source: NETIS (New Technology Information System), MLIT, Japan/ February, 2018)

3. Road surface condition survey (Road Surface Measuring/Evaluation, Vehicle, Digital Camera)

Name of advanced technology	**Simple Highway/Road Surface Condition Survey System by Small Vehicle**
	Suitable road survey for municipalities/towns/villages with many narrow roads (Road surface catcher)
Summary	Contents of advanced technology
	■ Technology to easily measure pavement road surface properties (cracks, rutting, and IRI) with compact vehicle
	Conventional technical correspondence
	■ Survey of road surface by road surface property measuring Vehicle: Analysed cracks, rutting and IRI of pavement with pavement property measuring vehicle of the size of about mini bus, and analysed according to the pavement survey test method manual.
	Application to public works
	■ Survey for properties of highway/road surface
	Others
	■ Acquire the highway/road surface properties (cracks, rutting and IRI) and forward image, GPS coordinates at the same time. ■ Cracks were conventionally evaluated by the mesh method, but they are evaluated simply by rank. ■ It is possible to create forms A and B of the draft guidelines for draft inspection (draft). ■ Survey of narrow roads is possible due to miniaturization of vehicles.

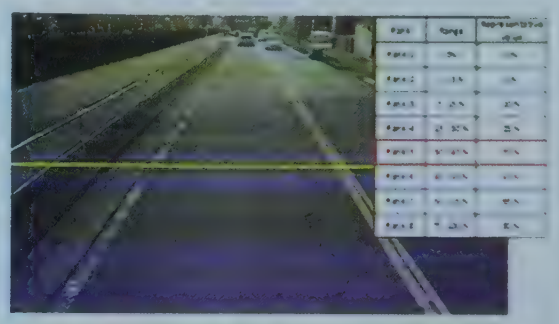
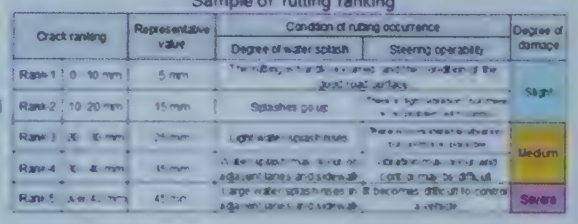
Comparison of advanced technology and conventional technology

Item	Advanced Technology	Conventional technology
Type of measuring vehicle	Automatic road surface image photographing vehicle	Road surface property measuring vehicle
Size of vehicle	Passenger vehicle	Mini bus
Ability to measure crack	Recognize width 3 mm or more	Recognize width 1 mm or more
Accuracy of rutting	Within ± 6 mm with respect to the road surface property measuring vehicle	Within ± 3 mm with respect to the transverse profile meter
Accuracy of flatness	-	Within ± 30 % with respect to the transverse profile meter
Accuracy of IRI (International Roughness Index)	Within ± 30 % with respect to the road surface property measuring vehicle	-
Number of staff	2	3
Measuring vehicle speed	0 - 60km/h	0 - 80km/h



Vehicle front view　　Vehicle rear view

<table>
<tr><td rowspan="2">Novelty and Expected Effects</td><td>Novelty and improvement (Compared to conventional technology)</td></tr>
<tr><td>■ The operability of the measuring vehicle has been simplified.
■ The method of analyzing the crack rate was changed to the method of evaluating the forward image by rank from the method of evaluating the road image by the mesh method.
■ Always give the on-board camera a swinging function linked with the steering wheel operation so that the road surface in front of the vehicle appears.
■ Dedicated analysis software for automatically creating Form-A and Form-B is created.</td></tr>
<tr><td rowspan="2"></td><td>Expected effect (Advantage of utilization of advanced technology)</td></tr>
<tr><td>■ Even 2 or 3 persons at the time of measurement can be provided, and measurement cost is reduced due to labour saving.
■ Changing the crack analysis method will save labour and reduce analysis cost.
■ By constantly photographing the road surface ahead, it is possible to ensure the quality of the crack analysis.
■ By using dedicated analysis software, it is easier to create Form-A and Form-B and save labour.

Sample of crack evaluation
 
Sample of rutting ranking
 
</td></tr>
<tr><td rowspan="8">Condition of application</td><td>Natural conditions</td></tr>
<tr><td>• Cannot be measured in case of rainfall
• Because it shoots with natural light, it cannot be measured at night time</td></tr>
<tr><td>Site conditions</td></tr>
<tr><td>• It cannot be measured with tunnels and underpasses where the brightness is insufficient</td></tr>
<tr><td>Technically available area</td></tr>
<tr><td>• Unlimited</td></tr>
<tr><td>Applicable laws and regulations</td></tr>
<tr><td>• Road traffic law</td></tr>
<tr><td rowspan="8">Scope of application</td><td>Applicable range</td></tr>
<tr><td>• Road where vehicles can travel normally (width 2.5m or more, height 2.8m or more)
• Paved road
• Measured speed range is 0 to 60 km/hr</td></tr>
<tr><td>Particularly effective application range</td></tr>
<tr><td>• Municipality/town/village road with many narrow spots</td></tr>
<tr><td>Unacceptable range</td></tr>
<tr><td>• Roads where vehicles cannot enter/pass through, such as sidewalks</td></tr>
</table>

<table>
<tr><td></td><td>Relevant criteria and source</td></tr>
<tr><td></td><td>• Pavement survey/Test method handbook, January 2010 Japan Road Association
• General inspection guidelines (draft), February 2013 MLIT Road Bureau
• Pavement Inspection Procedure, October 28, 2016 MLIT Road Bureau</td></tr>
<tr><td rowspan="8">Notice</td><td>Route selection/road design stage</td></tr>
<tr><td>• Information indicating the section of the route to be investigated (Road network diagram etc.) is required.</td></tr>
<tr><td>Construction stage</td></tr>
<tr><td>• Keep the distance to the vehicle ahead.</td></tr>
<tr><td>O&M stage</td></tr>
<tr><td>• None</td></tr>
<tr><td>Others</td></tr>
<tr><td>• None</td></tr>
<tr><td>Adaptability to hill roads in India</td><td>It is possible to perform a road surface condition survey (crack, rutting and IRI) by running a passenger car (Innova, others) and evaluate the road surface condition based on the data.</td></tr>
<tr><td>Expectation of application to model project</td><td>In introducing advanced technology, it is necessary to consider the following: (1)Condition of the candidate area (topography, features, environment, etc.), (2)Possibility of technical application, (3)Intention of the developer and the receiving side, (4)Effects of implementation and (5)Develop ability (future prospect).</td></tr>
<tr><td>Effectiveness of introducing advanced technology</td><td>Effectiveness: *reported by Developer
<table>
<tr><td colspan="4">Effectiveness of introduction</td></tr>
<tr><td>Comparative prior technology</td><td colspan="3">Investigation of road surface properties by road surface property measuring vehicle</td></tr>
<tr><td>Item</td><td colspan="2">Effect of introduction</td><td>Evaluation concept</td></tr>
<tr><td>Economic efficiency</td><td>✓Improvement (60%*)</td><td>Same level / Decrease</td><td>Cost reduction by using of compact measuring vehicles (small vehicle) and rank analysis of cracks.</td></tr>
<tr><td>Schedule</td><td>✓Shortening (45%*)</td><td>Same level / Increase</td><td>Simultaneous shooting of front images and shortening of process of preparing inspection formats with dedicated analysis software.</td></tr>
<tr><td>Quality</td><td>Improvement</td><td>✓Same level / Decrease</td><td>There is no difference in impact.</td></tr>
<tr><td>Safety</td><td>Improvement</td><td>✓Same level / Decrease</td><td>There is no difference in impact.</td></tr>
<tr><td>Workability</td><td>✓Improvement</td><td>Same level / Decrease</td><td>The number of personnel for measurement is reduced from 3 to 2 workers.</td></tr>
<tr><td>Impact on the surrounding environment</td><td>Improvement</td><td>✓Same level / Decrease</td><td>There is no difference in impact.</td></tr>
<tr><td>Selling points of technology</td><td colspan="3">It is confirmed that the crack rate by the rank evaluation can be evaluated equally to the crack rate by the mesh method, while reducing the cost while securing the accuracy.</td></tr>
</table></td></tr>
</table>

(Source: NETIS (New Technology Information System), MLIT, Japan/ February, 2018)

4. Other surveys (Information Board Control, Information System, Detective Sensor)

Name of advanced technology	**Simple Vehicle Detective Linkage System**
	System for automatically controls nearby and remote LED information boards according to vehicle speed information from the vehicle detective sensor
Summary	Contents of advanced technology
	■ Automatic control system for judging traffic conditions and linking with LED information devices.
	Conventional technical correspondence
	■ The worker judges the traffic condition every time and it manually switches the information on the LED information board on site.
	Application to public works
	■ Road repair/maintenance work and measures against traffic accidents
	Others
	■ By installing in a road section where there are many traffic jams, it can be used to call attention to vehicles. ■ Available for separation, such as measures against passing on narrow roads. ■ It can be used as a countermeasure against vehicle intrusion into construction regulations. When the vehicle approaches near the construction restriction, it detects the vehicle and displays warning signs on the LED information board. ■ Consultation with traffic administrators (police) may be necessary at designing and installing this technology. ■ Vehicle detection sensor corresponding to the following specifications can be connected. Serial communication protocol ■ Communication speed: 19.2 kbps ■ Data: 8 bits, ASCII ■ Stop bit: 1 bit ■ Parity: None Data contents +003 Speed (sign + 3 digits) +004: The output of RS232C outputs +000 even if speed will not bet detected.
Novelty and expected effects	Novelty and improvement (Compared to conventional technology)
	■ Changed the traffic condition judgment from a human to an automatic control system. ■ LED information contents have been changed from manual operation of the site worker to automatic.
	Expected effect (Advantage of utilization of advanced technology)
	■ By changing to the automatic control system, since confirmation of the condition at the site can be omitted, it is possible to increase/decrease the workability and cost.

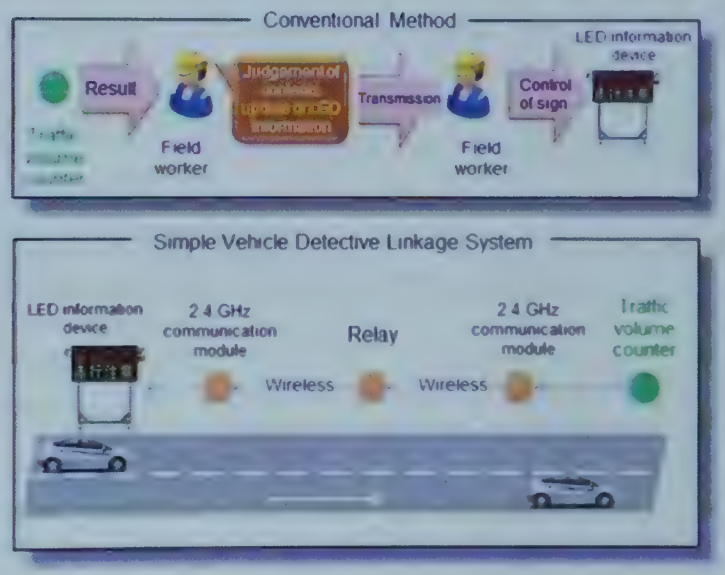


Image diagram of linkaged simple vehicle detection system

System operation benefits

Novelty	Expected effect
Automate artificial judgment	By exempting the condition check at the site, economic efficiency will be improved
Automate control of LED information device	Manpower can be decreased by exempting site change work

Condition of application	Natural conditions
	• None
	Site conditions
	• Installation space per vehicle detection sensor: 0.6m x 1.6m (0.96 m^2) • LED information board (2 series) - Installation space per unit: 1.2m x 1.6m (1.92 m^2)
	Technically available area
	• Unlimited
	Applicable laws and regulations
	• None
Scope of application	Applicable range
	• Location where power supply can be secured. • Location where communication between vehicle detection sensor and LED information board will be possible.
	Particularly effective application range
	• Because it can automatically determine traffic congestion, it is used in a road section where traffic jam is likely to occur. • Use in road sections where accidents are frequent due to over speeding. • Use in road sections where vehicle separation occurs.
	Unacceptable range
	• Location where power supply cannot be secured. • Location where communication between the vehicle detection sensor and LED information board will be impossible.
	Relevant criteria and source
	• None
Notice	Route selection/road design stage
	• Housing (Cover) will be required if a rapid temperature rise in the equipment due to sunlight is expected. • When designing the technology, consultation with traffic administrators (police) may be necessaries.
	Construction stage
	• When installing devices, it is necessary to check the communication condition between the vehicle detection sensor and the LED information board. • Power supply for each device such as vehicle detective sensor, controller and information board will be necessary. • Equipment installation will be required. • When constructing the technology, consultation with traffic administrators (police) may be necessary.
	O&M stage
	• When using a battery as a power supply for each device, battery residual capacity management will be required.
	Others
	• Each device has been water-proof and dust-proof.
Adaptability to hill roads in India	It is possible to ensure the safety/smooth traffic flow using automatic control of judgment of traffic condition and LED information board. On the hill roads in India, this system will be available for the "Gate System".
Expectation of application to model project	In introducing advanced technology, it is necessary to consider the following: (1)Condition of the candidate area (topography, features, environment, etc.), (2)Possibility of technical application, (3)Intention of the developer and the receiving side, (4)Effects of implementation and (5)Develop ability (future prospect).

Effectiveness of introducing advanced technology

Effectiveness: *reported by Developer

Effectiveness of introduction				
Comparative prior technology	The worker judges the traffic situation and manually changes the sentences of the LED display board (VMS) on the site.			
Item	Effect of introduction			Evaluation concept
Economic efficiency	✓Improvement (64%*)	Same level	Decrease	Skip the local traffic condition check
Schedule	Improvement	✓Same level	Increase	There is no difference in impact.
Quality	Improvement	✓Same level	Decrease	There is no difference in impact.
Safety	Improvement	✓Same level	Decrease	There is no difference in impact.
Workability	✓Improvement	Same level	Decrease	Since confirmation and change work at the site can be omitted, traffic control work is improved.
Impact on the surrounding environment	Improvement	✓Same level	Decrease	There is no difference in impact.
Selling points of technology	Conventional technology was checking traffic conditions locally, so there was a problem in terms of economy and workability. By utilizing this technology, it is possible to omit the site situation confirmation and the text change of the LED information board, so it can save labour and improve economic efficiency.			

(Source: NETIS (New Technology Information System), MLIT, Japan/ February, 2018)